Sensor Model Language (SensorML) and Sensor Web Enablement (SWE)

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OGC®
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SensorML

What is SensorML?

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- **Models and XML encodings for describing processes**
  - Detectors, actuators, etc. are modeled as processes
  - Can be used to describe “left-side” processes (“how were these observations obtained?”) and “right-side” processes (“what can I derive from these observations?”)
- **Vision:**

  - **Discovery of transducers and processes / plug-n-play sensors** – SensorML is the means by which sensors and processes make themselves and their capabilities known
  - **Observation lineage** – SensorML provides sensing and processing history of observations; supports quality knowledge of observations
  - **On-demand processing** – SensorML supports on-demand derivation of higher-level information (e.g. geolocation or products) without a priori knowledge of the sensor system
  - **Intelligent, autonomous sensor network** – SensorML enables the development of taskable, adaptable sensor networks

  - **Network and software friendly** – SensorML is ideal for distributing processing demands throughout the network/command hierarchy
  - **Extensibility** – SensorML provides easy means for meeting various community needs

Real-Time Management of Sensor Web Assets

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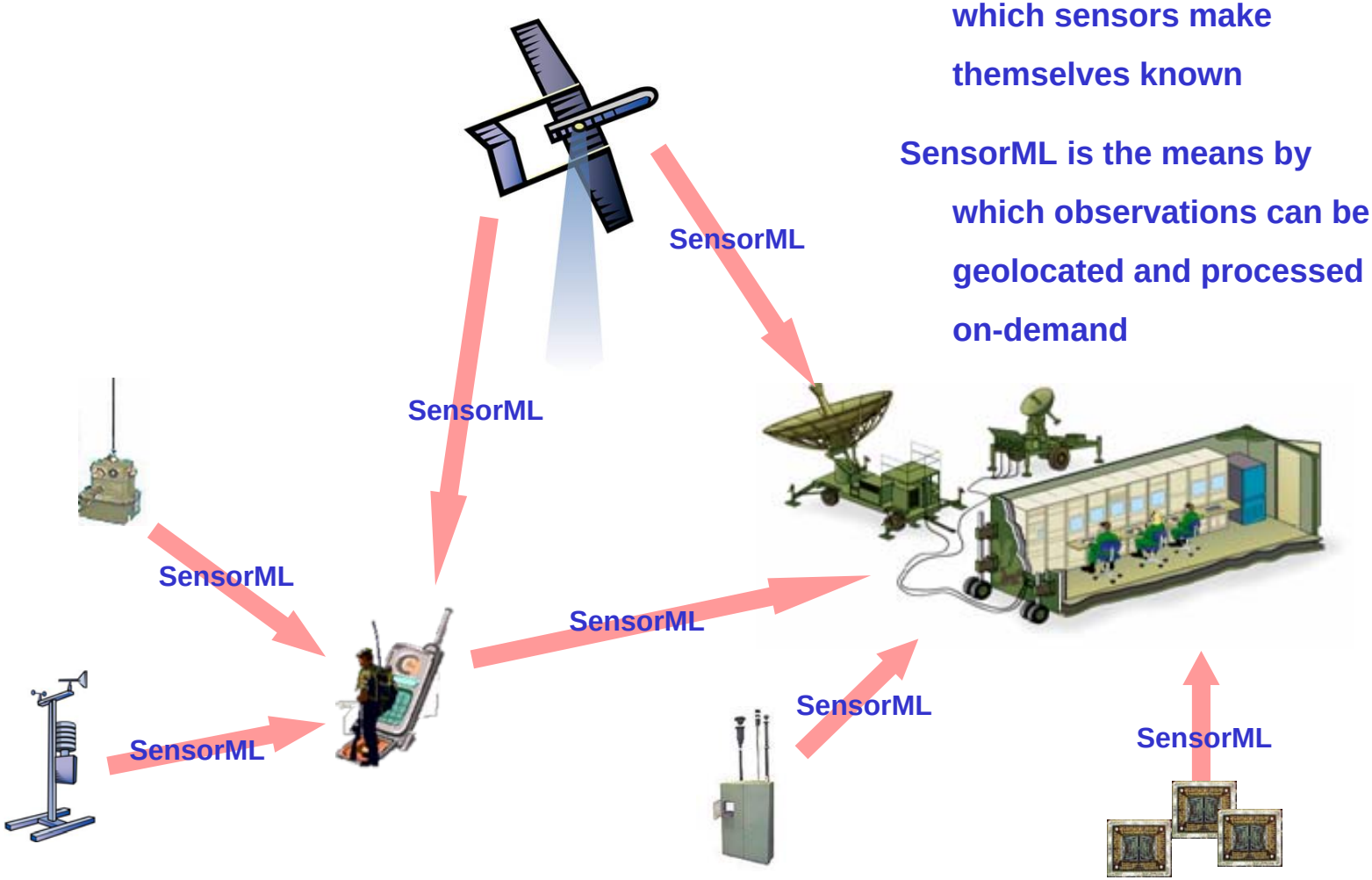
SensorML is the means by which sensors make themselves known

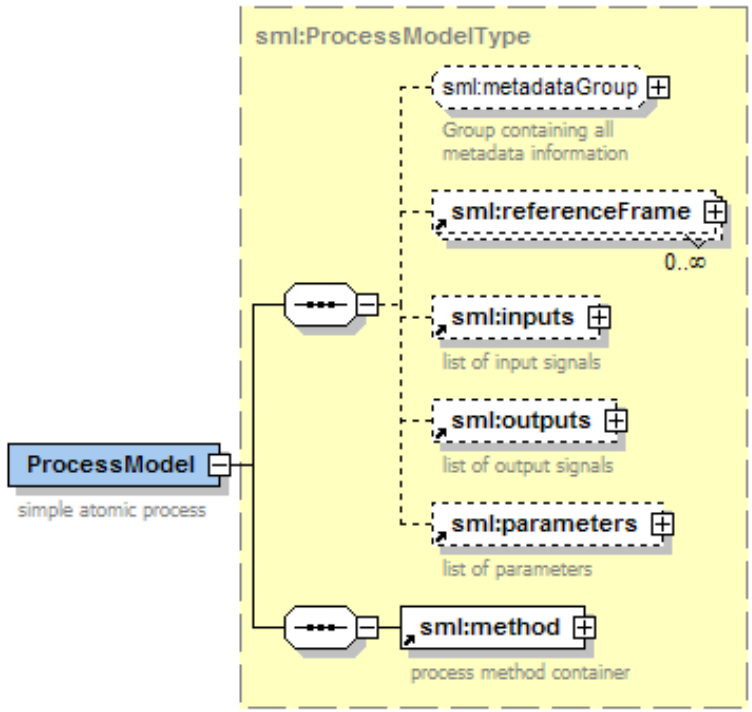
SensorML is the means by which observations can be geolocated and processed on-demand



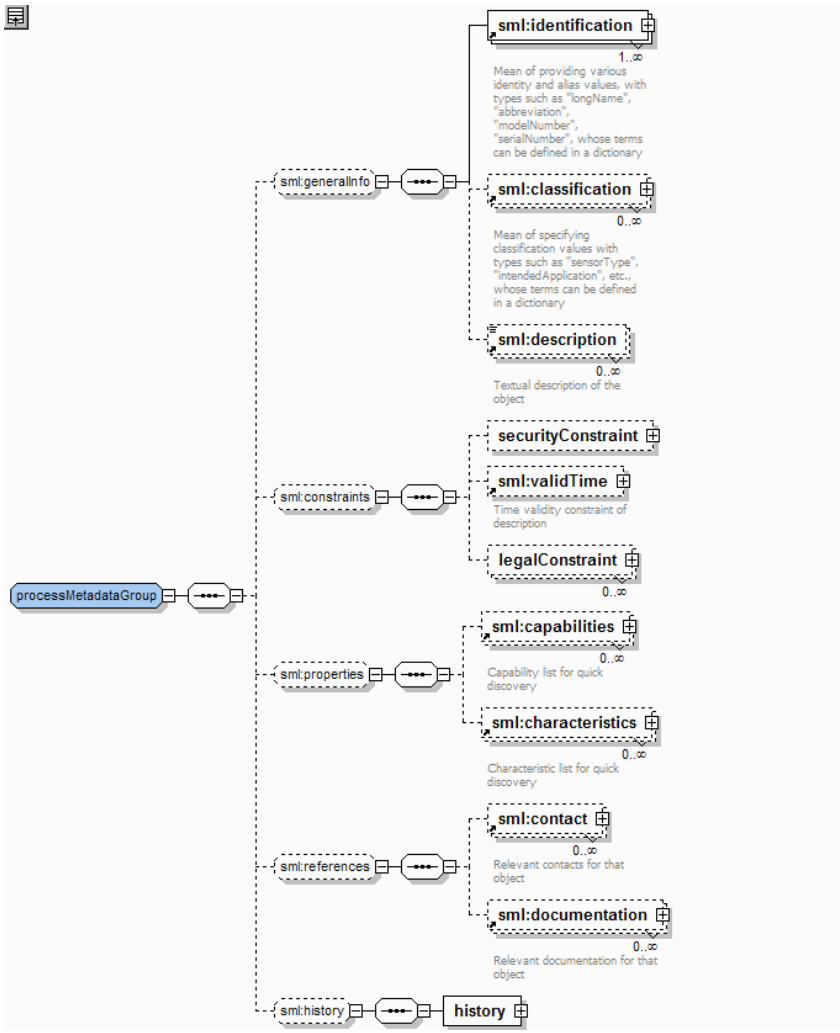
SensorML Process Model (Normative)

In SensorML, everything is modeled as a Process

- **ProcessModel / Component**
  - defines atomic process modules (detector being one)
  - has five sections
    - metadata
    - inputs, outputs, parameters
    - method
  - Inputs, outputs, and parameters defined using SWE Common data definitions



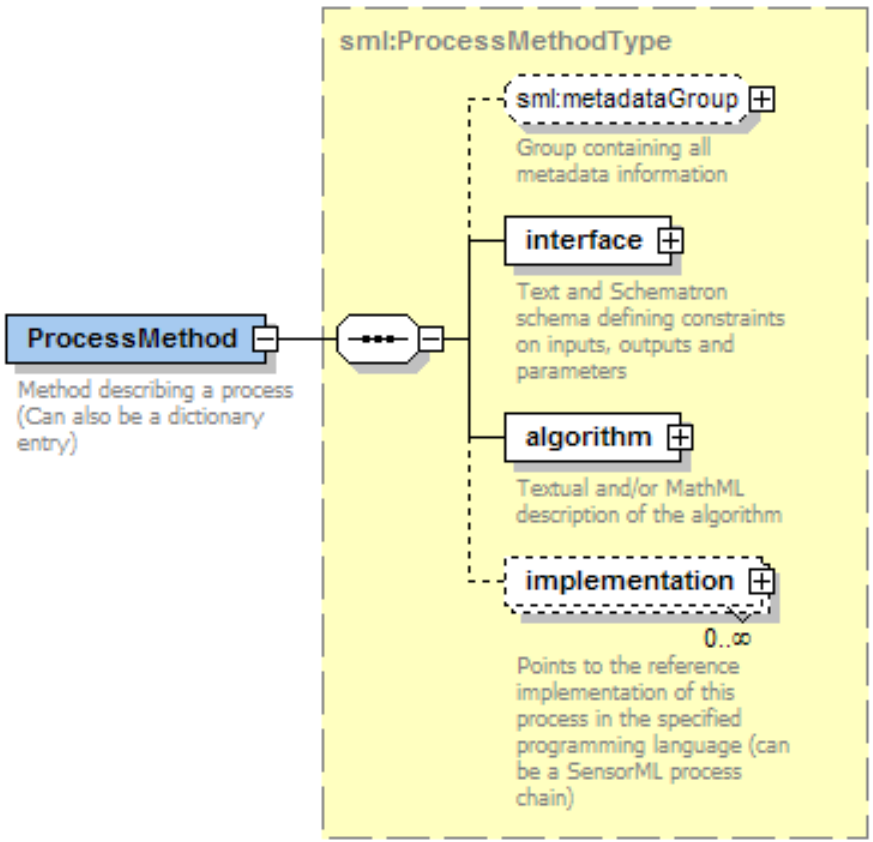
Process/Sensor/System Metadata (Normative)



Metadata is primarily for discovery and assistance, and not typically used within process execution

- **Includes**
  - Identification, classification, description
  - Security, legal, and time constraints
  - Capabilities and characteristics
  - Contacts and documentation
  - History

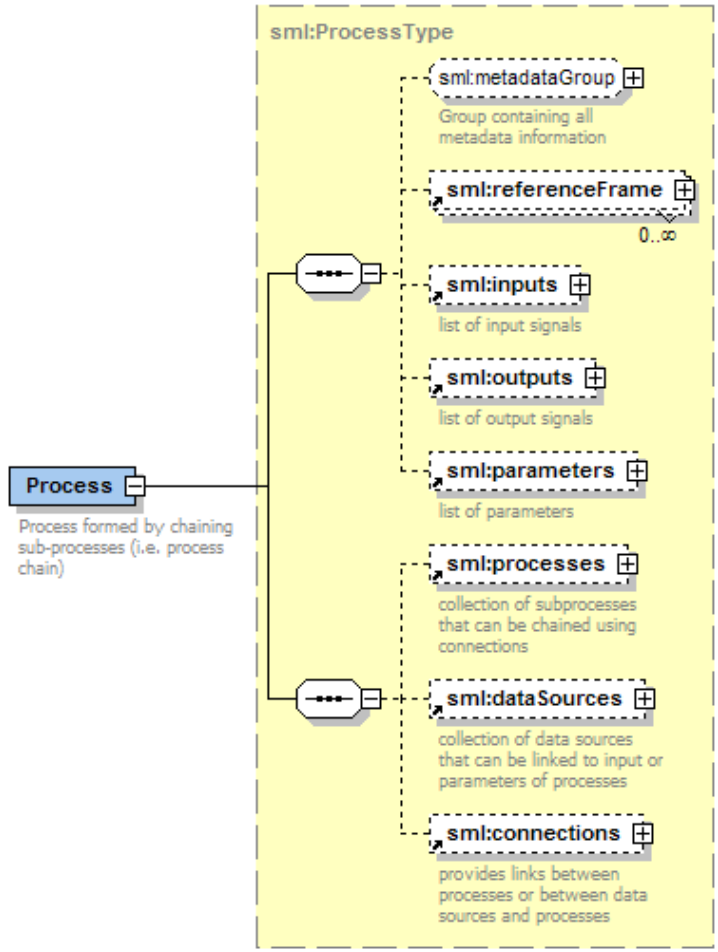
Process Method



- **Metadata group** has same properties as ProcessModel
- **Interface** supports schematron-based validation of XML instance
- **Algorithm** allows textual or MathML description of process
- **Implementation** points to various implementation
  - Java, C, MathML
  - WPS implementation
  - CSM API implementation

SensorML Process Chain (Normative)

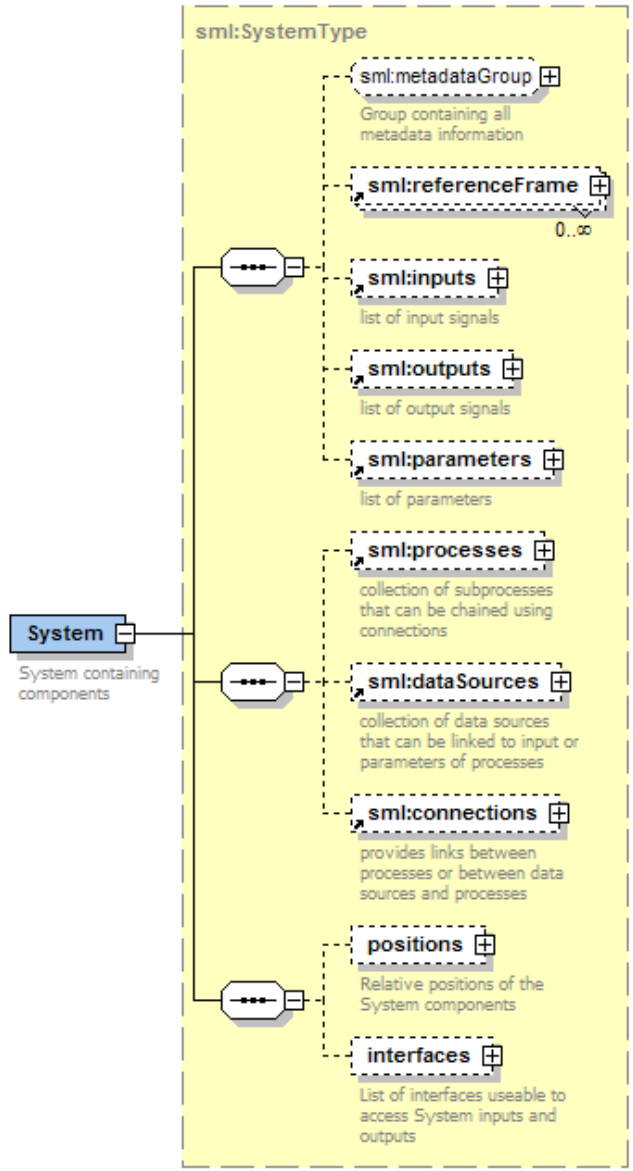
- **ProcessChain**
  - defines a process chain
  - includes:
    - metadata
    - inputs, outputs, and parameters
    - processes (ProcessModel, Process)
    - data sources
    - connections between processes and between processes and data
- **System**
  - defines a collection of related processes along with positional information



SensorML System (Normative)

System

- A system relates a collections of processes to the real world
- Provides relative position of components by defining the relationship between their coordinate frames
- Provides a description of the System interfaces for command and output



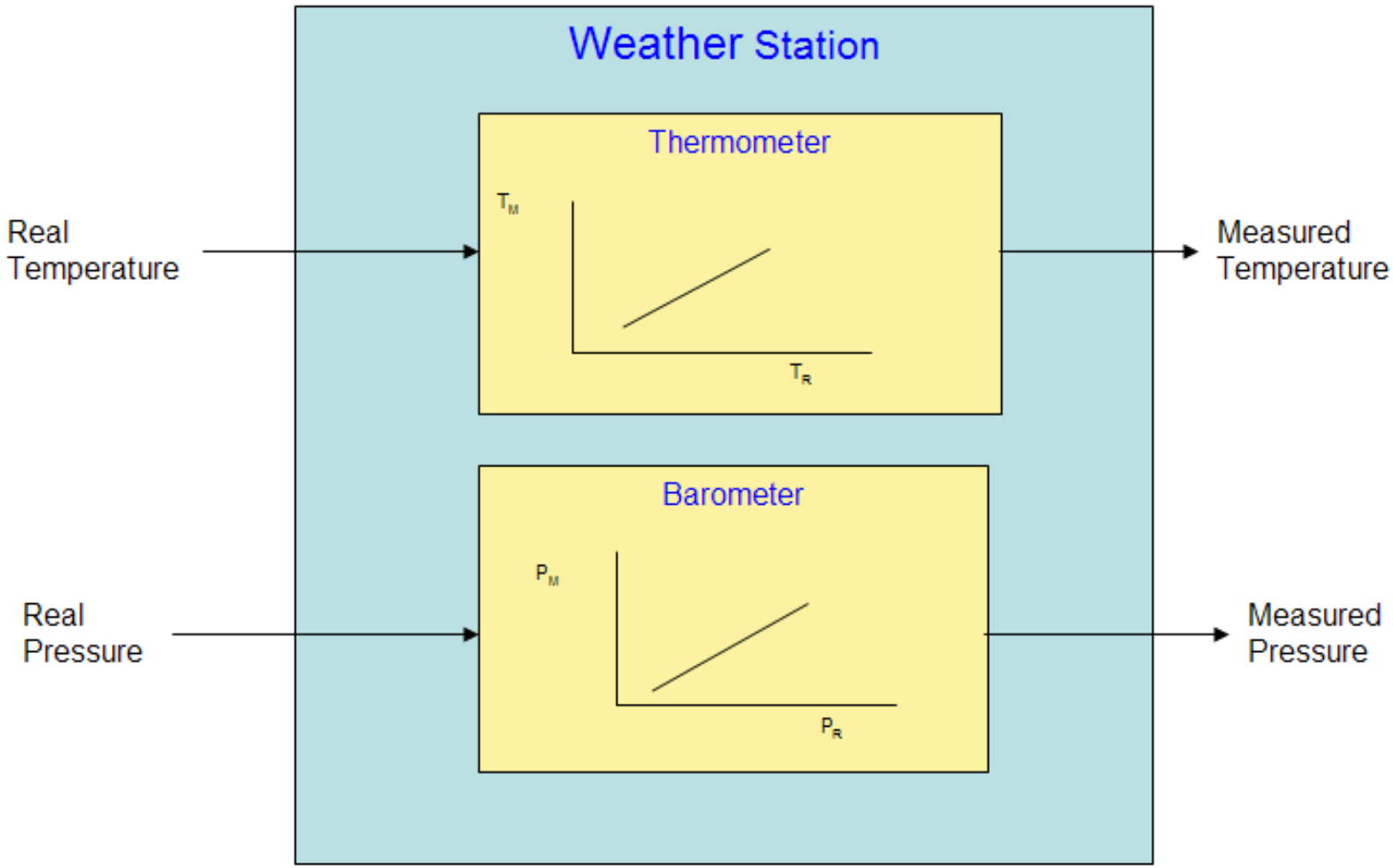
How SensorML can be used -1-

- **“Left-side” versus “Right-side” use**
  - **“Left-Side”**
    - Describes how existing data was obtained
    - Traditional approach
    - Relies on software that has knowledge of sensor system and how to apply particular parameters
    - Useful for defining lineage of observations
    - Useful for simulations of sensor system
  - **“Right-Side”**
    - Describes how to take existing data and derive on-demand higher level information
    - Our vision on how we support discovery and processing of previously unknown observations without a priori knowledge of the sensor system
    - Can utilize process models and parameters from left-side processes

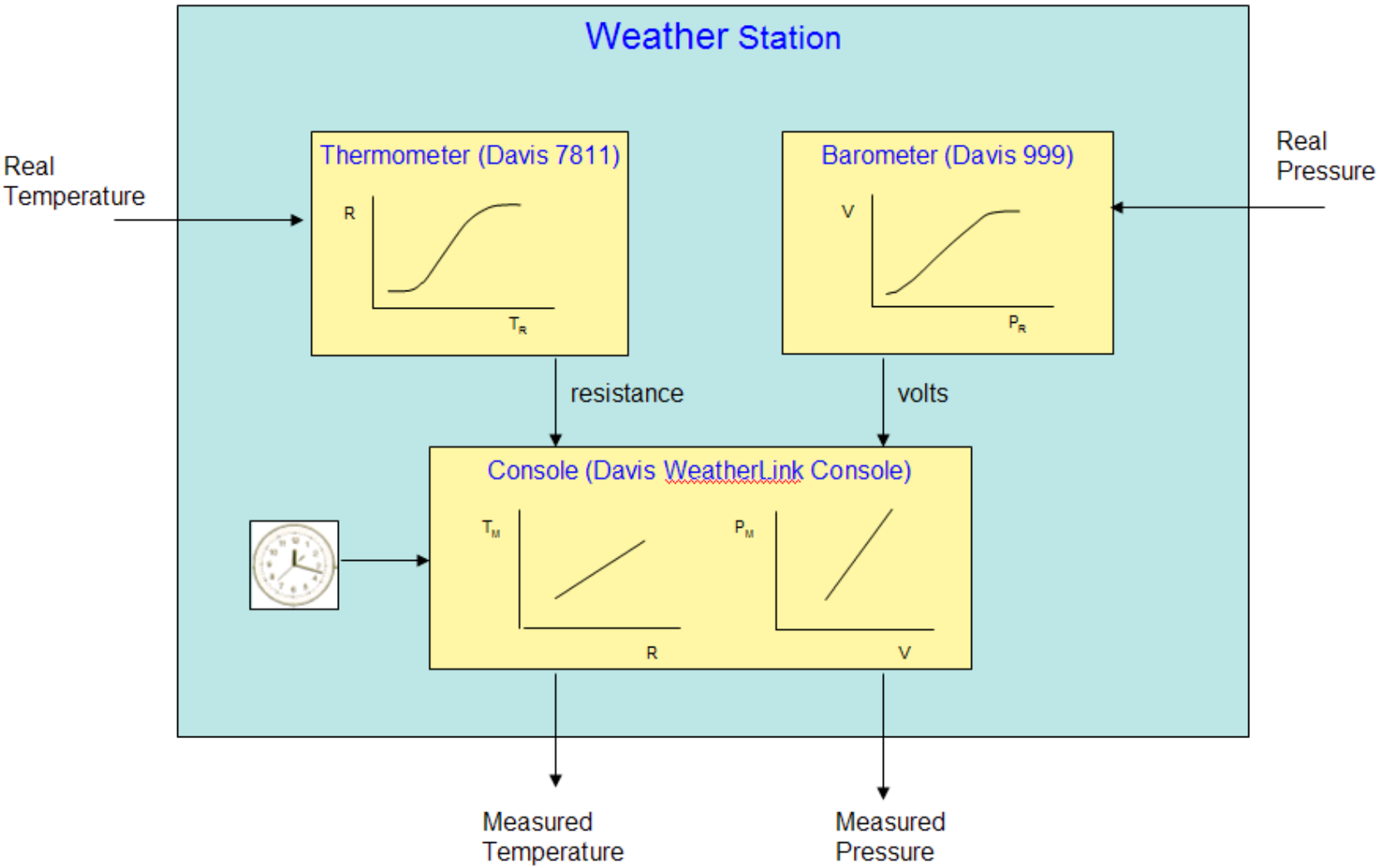
How SensorML can be used -2-

- **Time instance of process versus process factory**
  - **Time instance of process**
    - Typically might accompany a particular instance of an observation and be valid for that time
    - All parameter values for the process are defined inline
    - SPOT DIMAP and NITF approach
  - **Process Factory**
    - Process is defined but variable parameter values may not be specified
    - One treats process like factory assembly line; supply appropriate parameter values and then pump through the input values to obtain appropriate output values

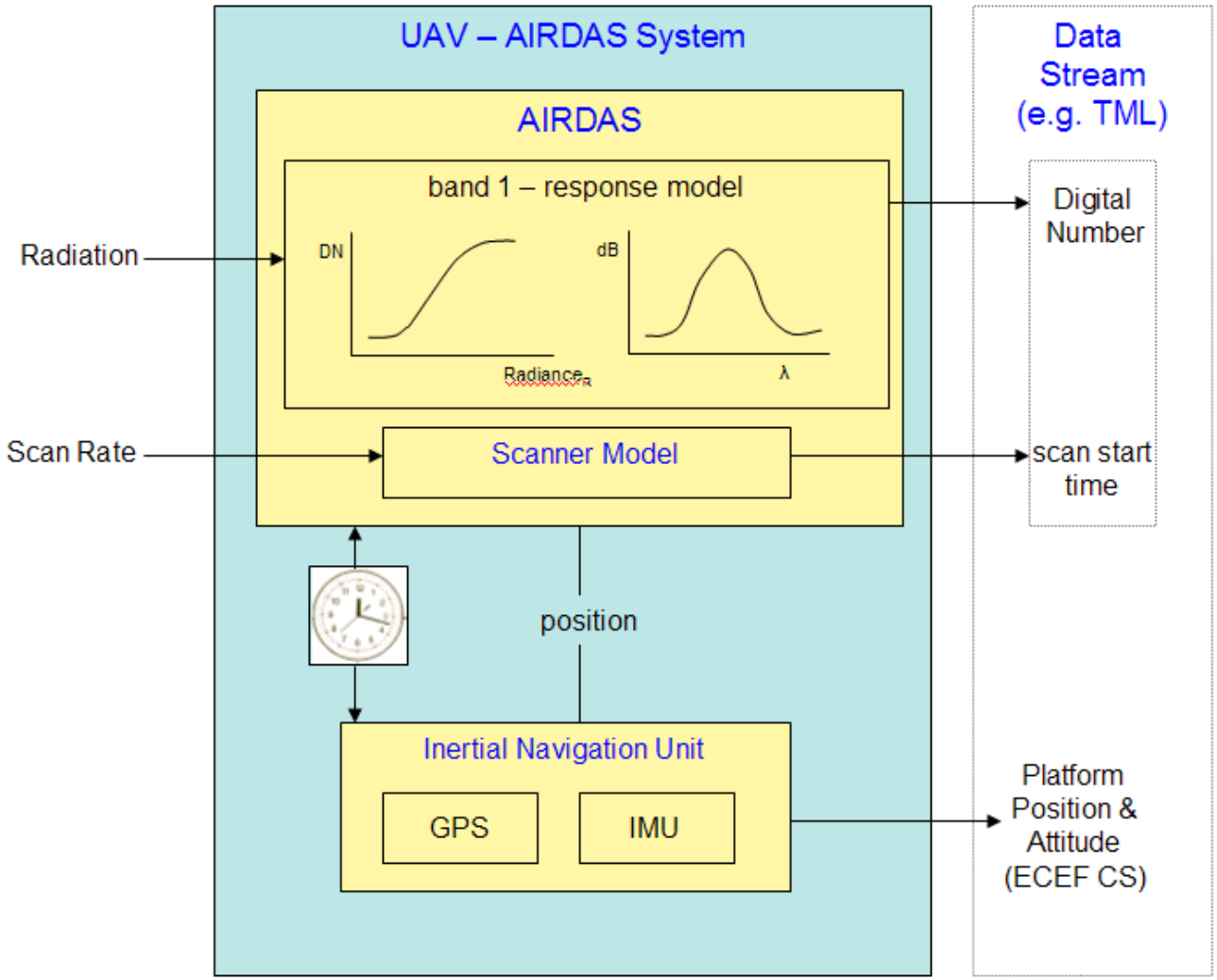
System Example – Simple Weather Station



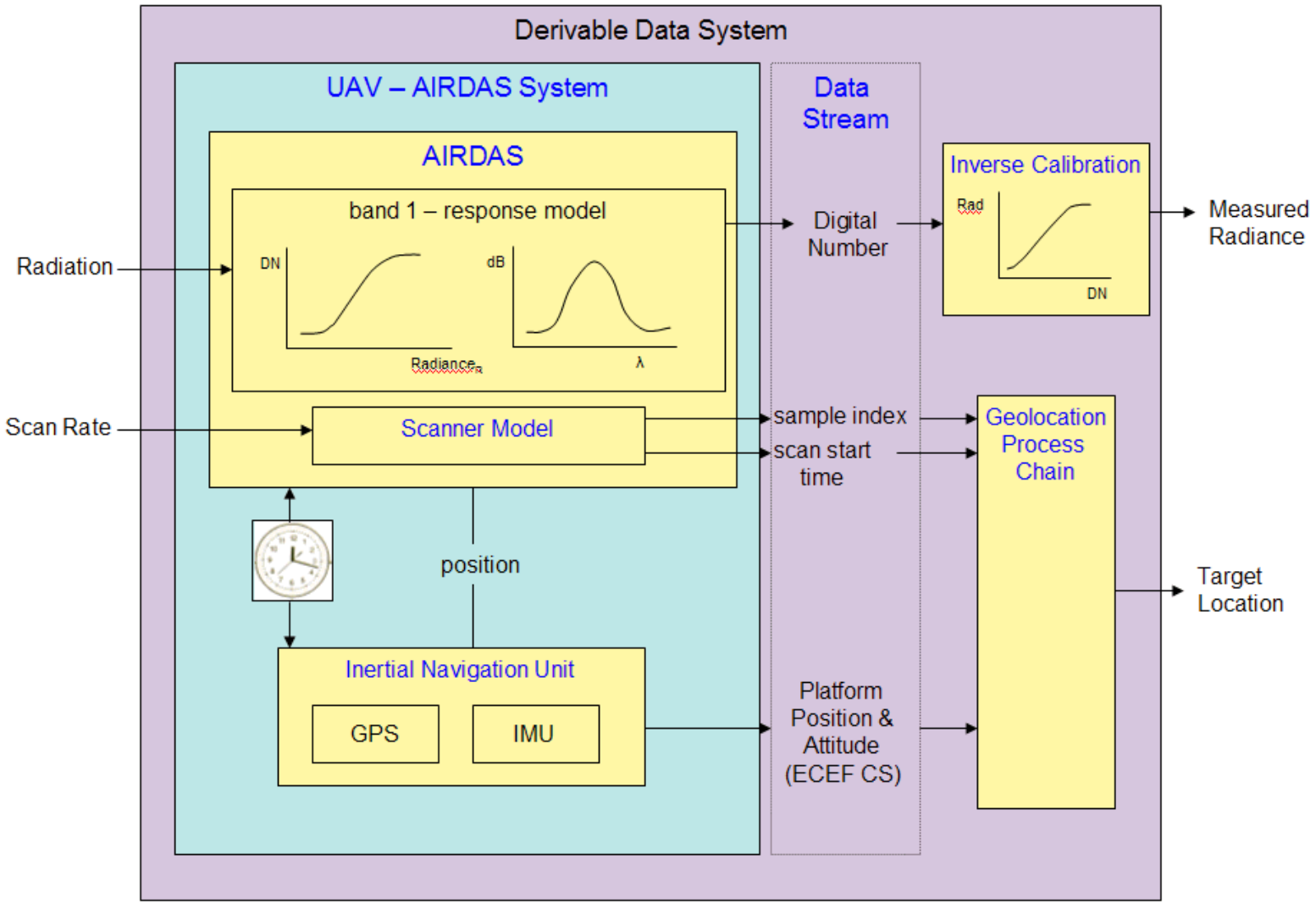
System Example – More explicit weather station



System Example – Basic UAV-AIRDAS system



System Example – AIRDAS with derivable data



Example Process Models (Informative)

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- Transducers (detectors, actuators, samplers, etc.)
- Spatial transforms (static and dynamic)
  - Vector, matrix, quaternion operators
  - "Sensor models"
    - scanners, frame cameras, SAR
    - polynomial models (e.g. RPC, RSM)
    - tie point model
  - Orbital models
  - Geospatial transformations (Map projection, datum, coordinate system)
- Digital Signal Processing / image processing modules
- Decimators, interpolators, synchronizers, etc.
- Data readers, writers, and access services
- Human analysts

General Detector Model (Informative)

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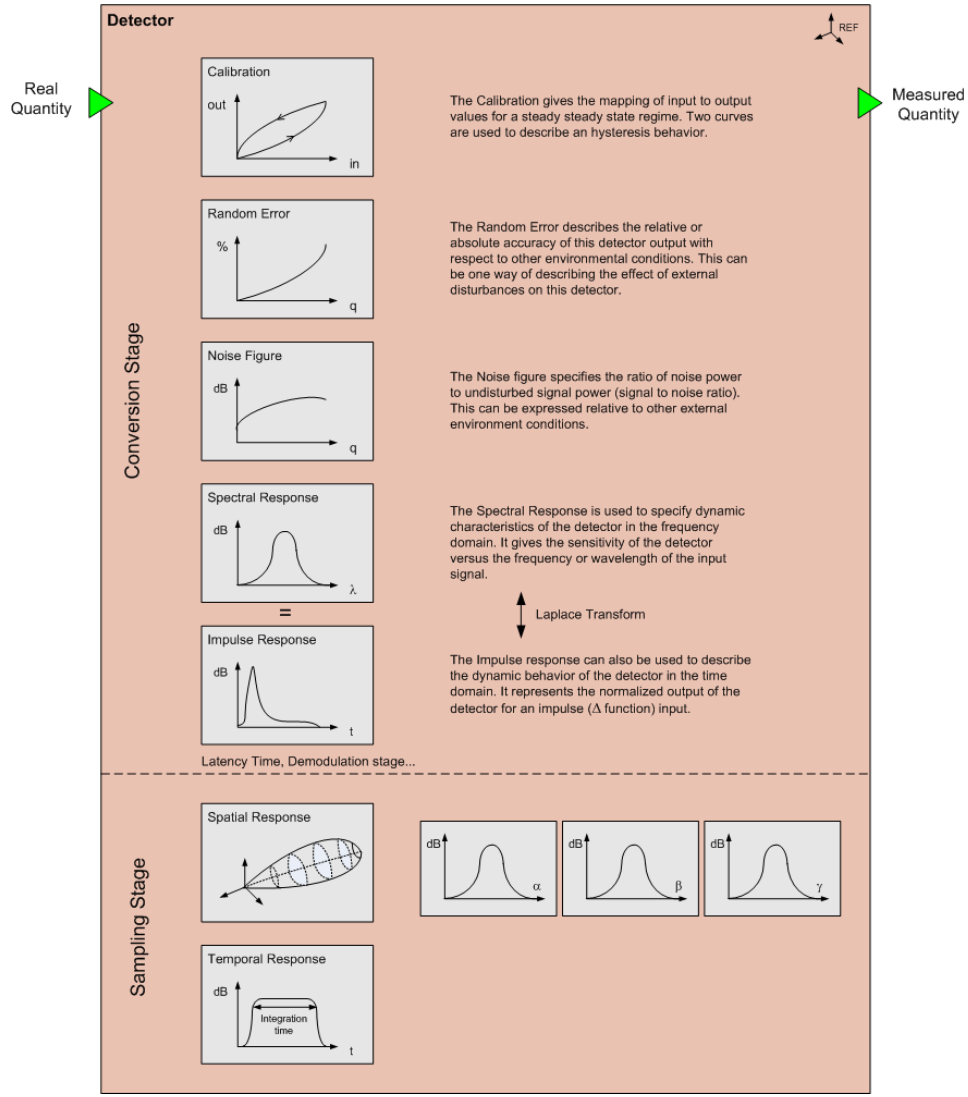
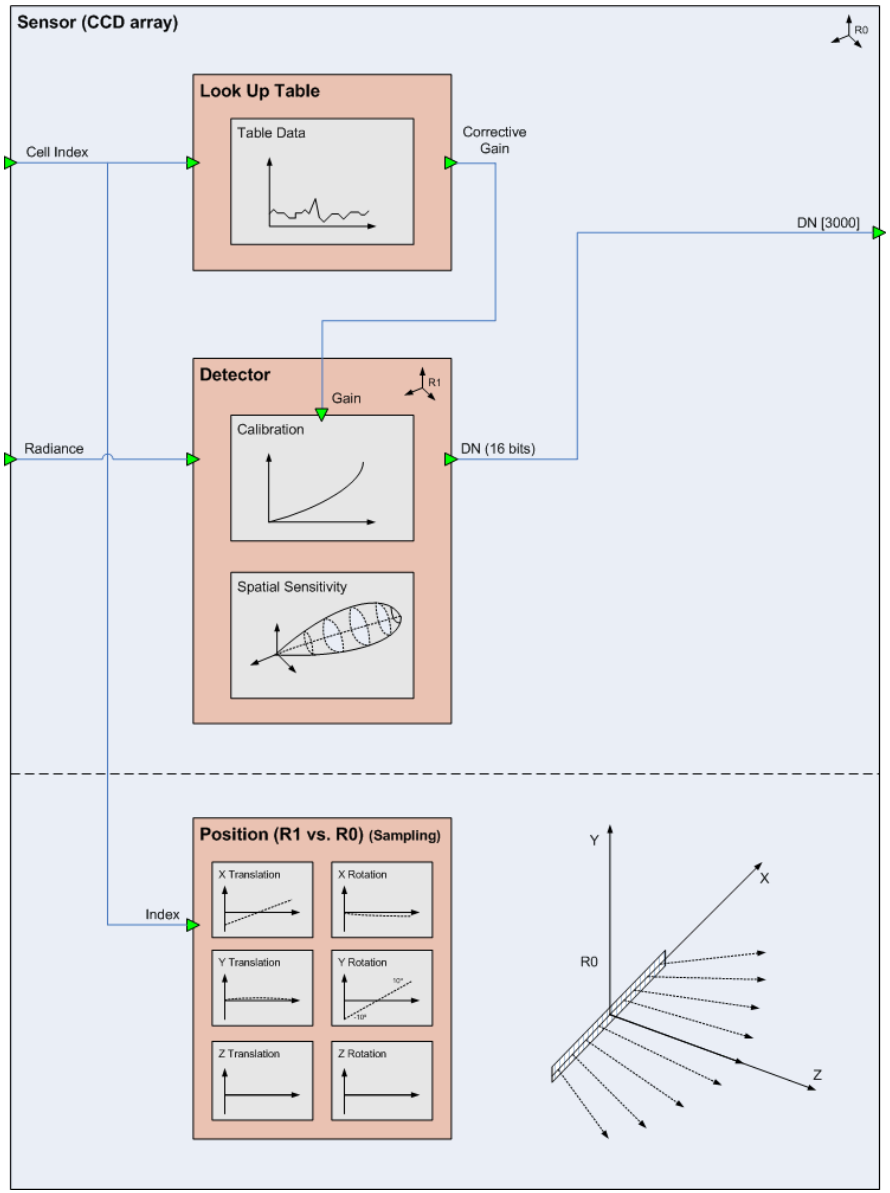
- Potentially one of the most complex process models
- All parameters expressed in SensorML as curves
- Describes response of a single detector (e.g. thermometer, pixel, etc.)

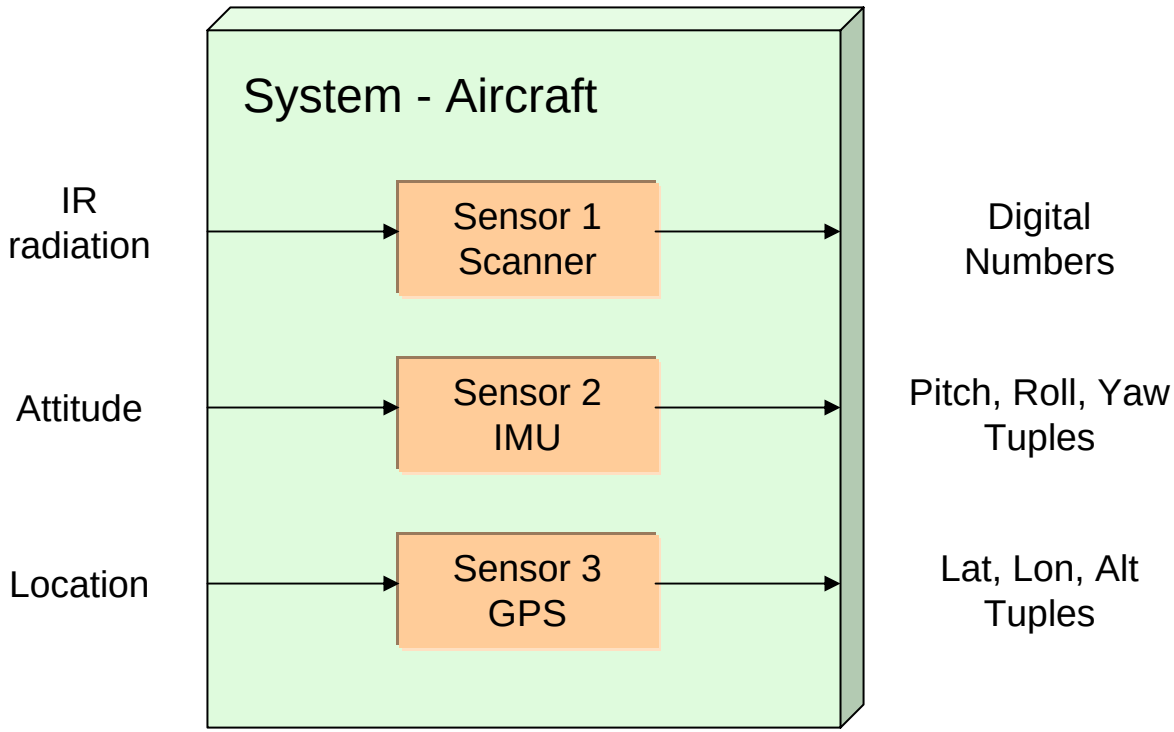


General Detector Array Model (Informative)

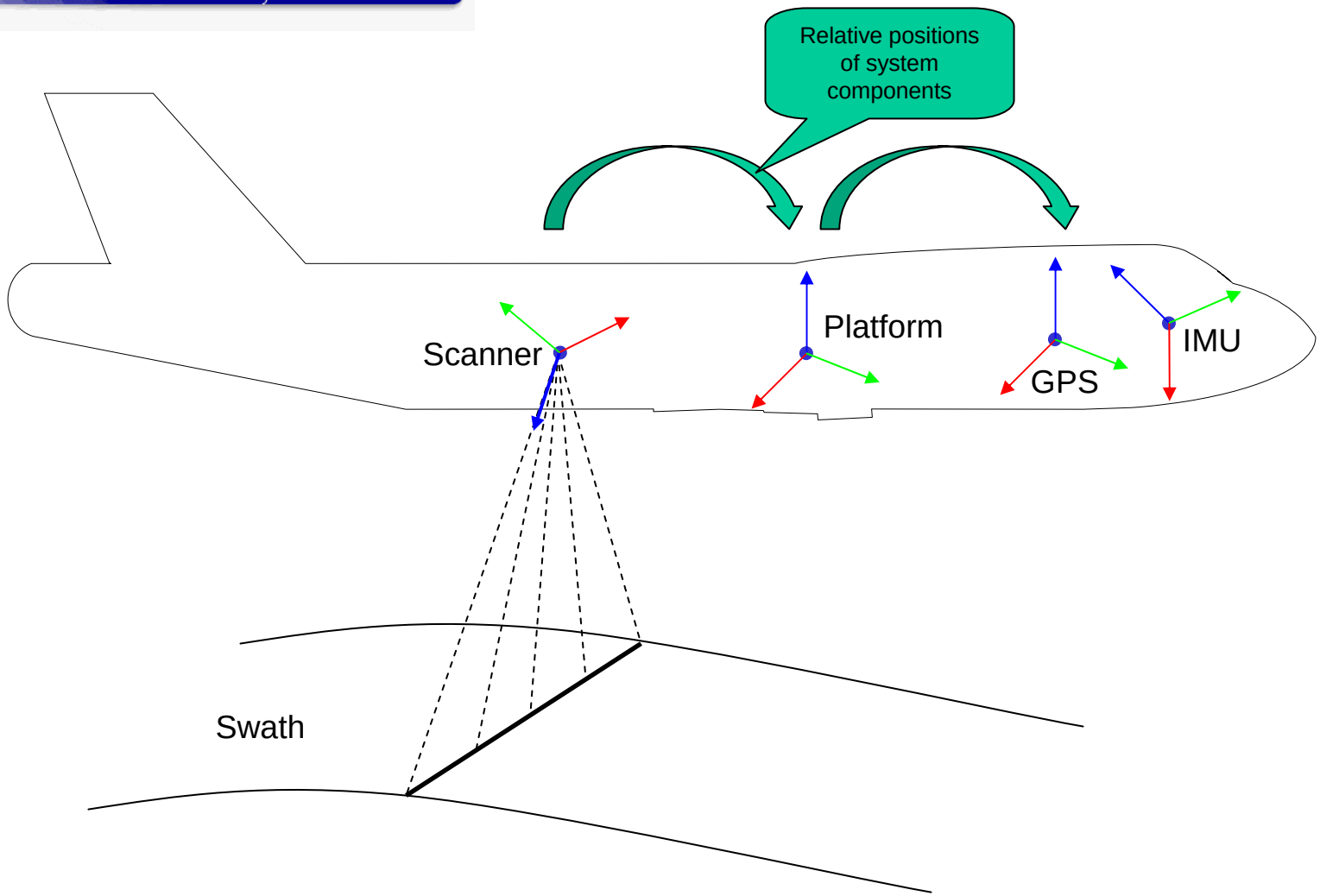
- Detector Array modeled as a System
- Constant properties of individual detectors supported by the Detector ProcessModel
- Variable response of individual detectors supported by index dependent curves (e.g. gain vs. index)
- Spatial variability (e.g. Look ray direction) also supported using index driven curve



SensorML – Sensor Systems



SensorML – Relative Positions



AIRDAS UAV Geolocation Process Chain (Informative)

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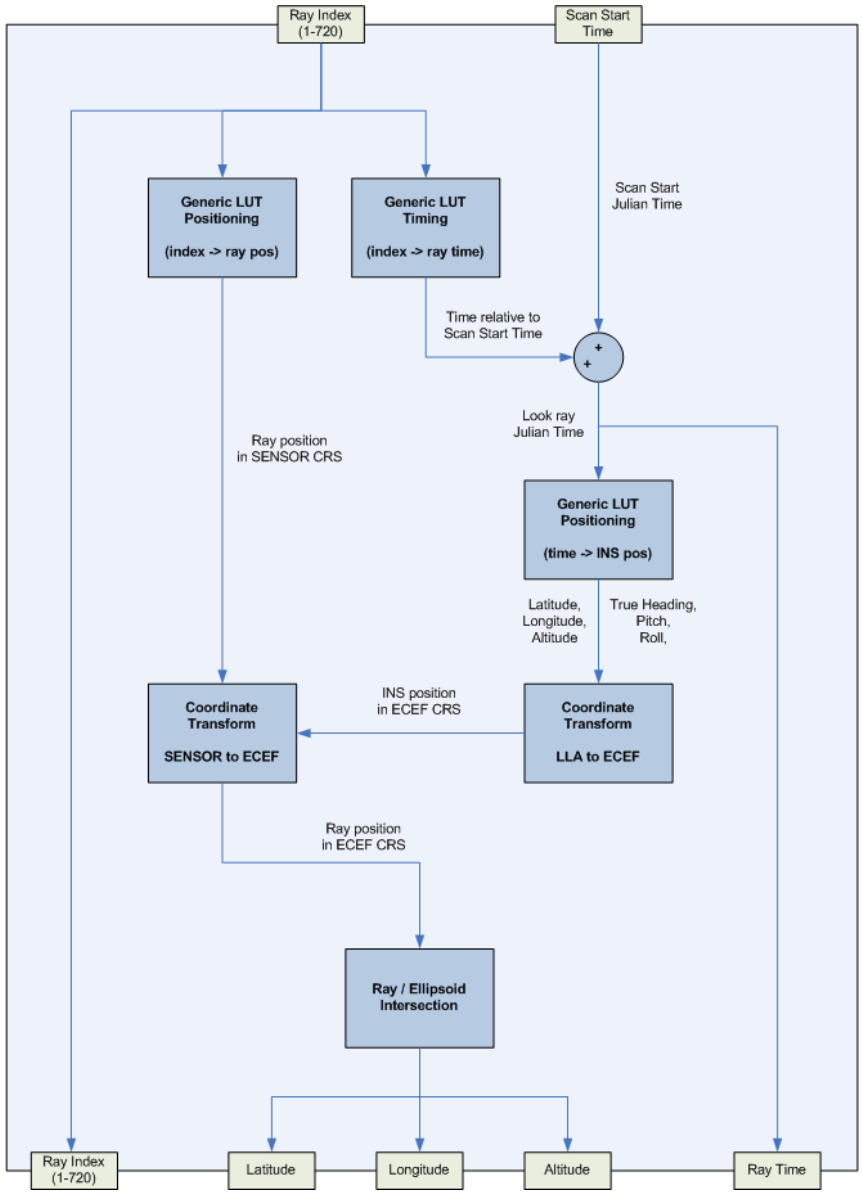
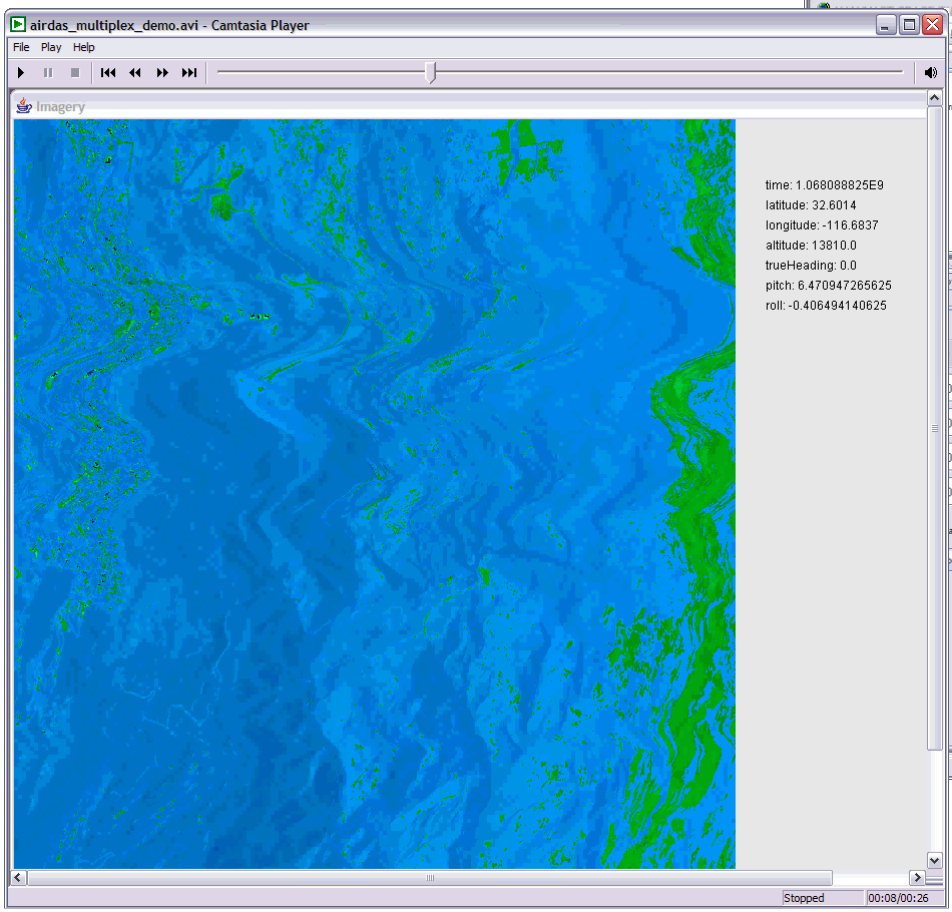
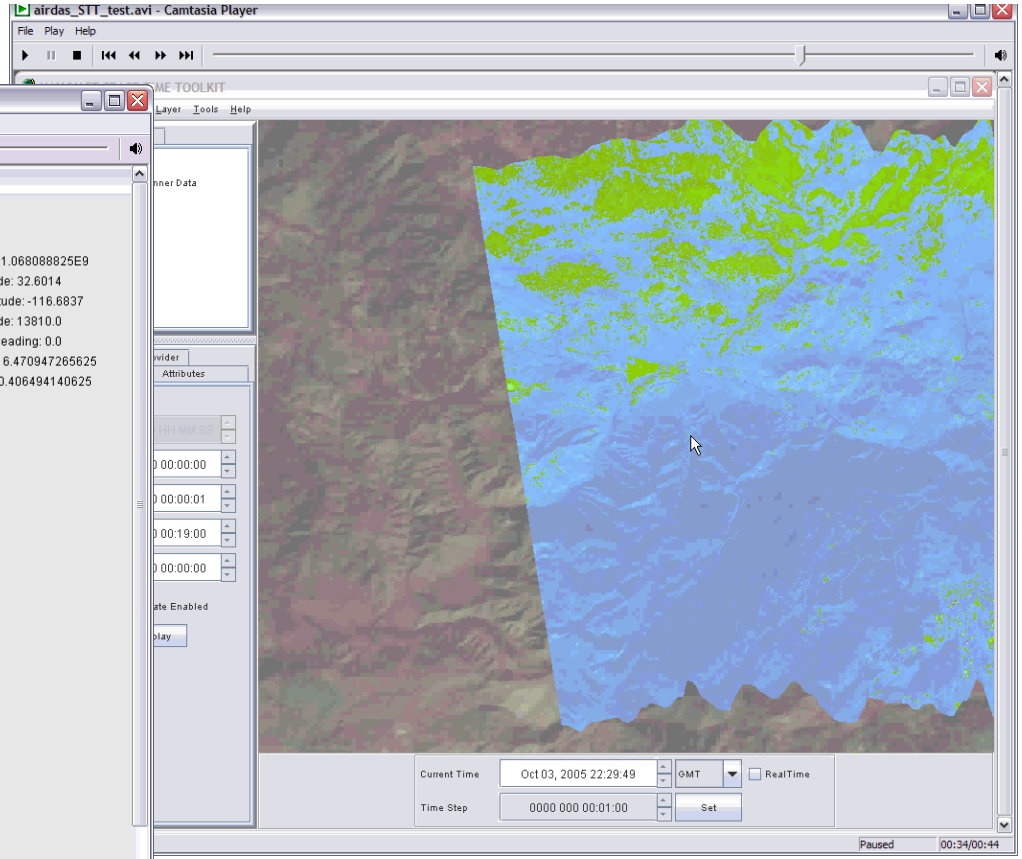
- **Inputs:**
  - Ray index
  - Scan start time
- **Outputs:**
  - Ray index
  - Latitude, longitude, altitude
  - Ray time
- **Process Models used**
  - LUTs
    - Index to ray direction
    - Index to ray time offset
    - Time to UAV state
  - Coordinate Transforms
  - Ray-Ellipsoid intersection



AIRDAS UAV Geolocation Process Chain Demo





AIRDAS data stream (consisting of navigation data and 4-band thermal-IR scanline data)

AIRDAS data stream geolocated using SensorML-defined process chain (software has no a priori knowledge of sensor system)

Status of SensorML Specification -1-

- **SensorML Core (Normative)**
  - Core framework models and encoding complete and stable
  - SensorML history
    - Started at UAH in 1998; brought into OGC in 2000
    - Approved as Public Discussion Paper (2002)
    - Approved as Recommended Paper (2004)
    - OGC 05-086 approved as Best Practices Document in Bonn (Nov 2005)
  - Current: document (OGC 05-085r2); schema (2006-02-21)
  - SensorML on track for OGC Technical Specification
    - Gathering and documenting current implementations
    - Approved for RFC in Huntsville TC (March 2006)
    - Approved on July 24 as V0.0 Specification
    - RWG will consider submitted comments and release final V1.0 for approval (60 day vote)

Status of SensorML Specification -2-

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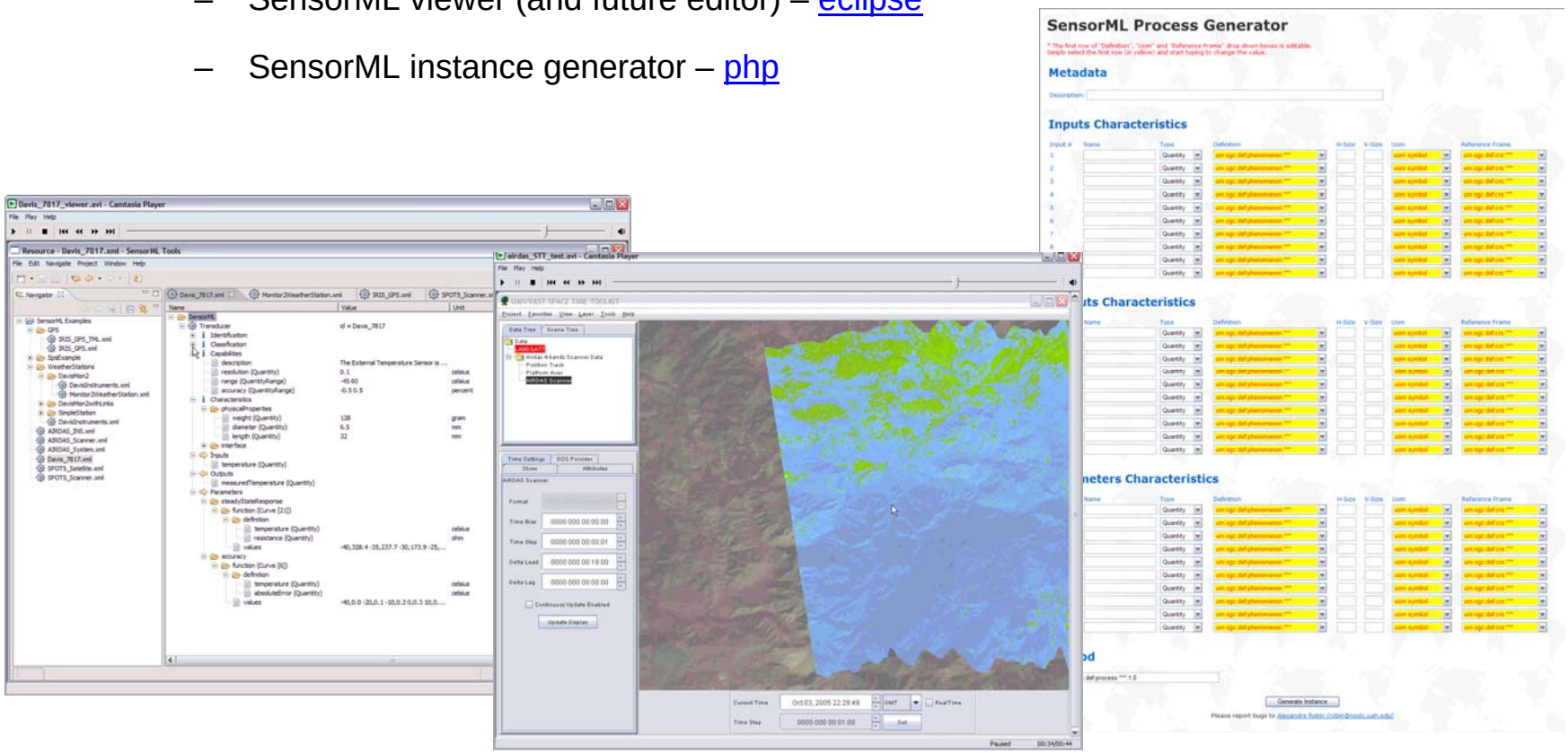
- **SensorML Forum (Informative)**
  - Established for information exchange (currently 160+ subscribers)
  - http://mail.opengeospatial.org/mailman/listinfo/sensorml
- **SensorML Process Models (Informative)**
  - Have established SourceForge project for ProcessModel submission and download
  - Have developed Open Source SensorML parser and process execution environment
  - Have developed API for Java process model software
- **SensorML White Papers and Tutorials (Informative)**
  - Creating Simple System
  - Creating Process Models
  - SPOT Image System, AIRDAS System Tutorial (coming soon)

Status of SensorML Specification -3-

- **SensorML Open Source Software (Informative)**
  - SensorML parser and chain executor – java
  - SensorML viewer (and future editor) – eclipse
  - SensorML instance generator – php



Recommendations to Net-Ready Sensors Workshop

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- Consider supporting community models in SensorML
  - Mapping of IEEE P1451 to SensorML is currently underway
  - N42.42 is very compatible with SensorML detector structure
  - Initial investigation indicates CRBN standard is compatible with SensorML
- Advantages
  - SensorML utilizes soft-typing so most mapping primarily involves defining community-approved dictionary (registry) of terms
  - Extensive work and expertise that has been put into community models can be supported in an interdisciplinary (and interoperable) standard
  - Discoverable based on metadata and model characteristics
  - Community Model instances can participate as part of a SensorML processing chain
  - Can include CRBNE/N42.42/IEEE 1451 sensor instances as part of the lineage chain provided by SensorML

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Sensor Web Enablement





Sensors Are Everywhere








Basic Desires

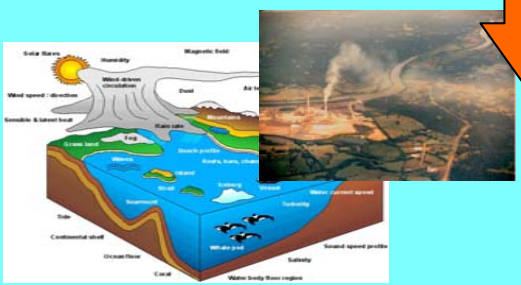
- Quickly discover sensors and sensor data (secure or public) that can meet my needs – location, observables, quality, ability to task
- Obtain sensor information in a standard encoding that is understandable by me and my software
- Readily access sensor observations in a common manner, and in a form specific to my needs
- Task sensors, when possible, to meet my specific needs
- Subscribe to and receive alerts when a sensor measures a particular phenomenon

Sensor Web Enablement Framework

Heterogeneous sensor network

- sparse
- disparate
- mobile/in-situ
- extensible

Models and Simulations



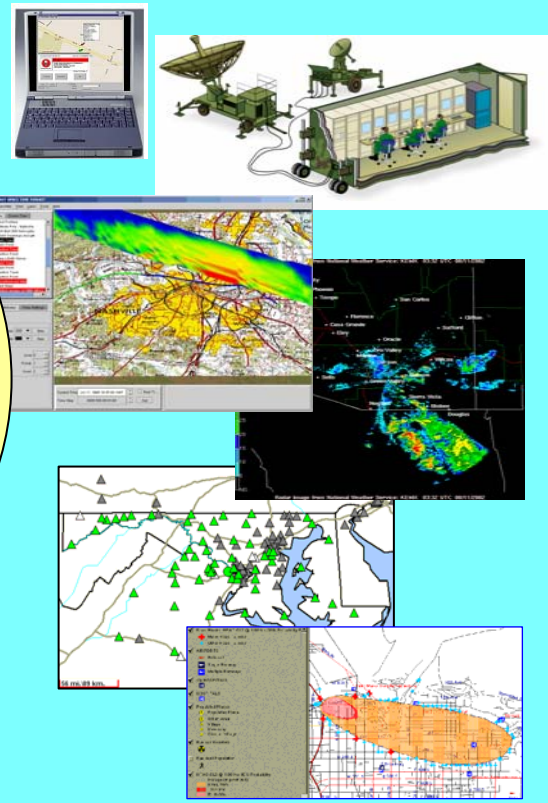
- nested
- national, regional, urban
- adaptable
- data assimilation

Sensor Web Enablement

- discovery
- access
- tasking
- alert notification

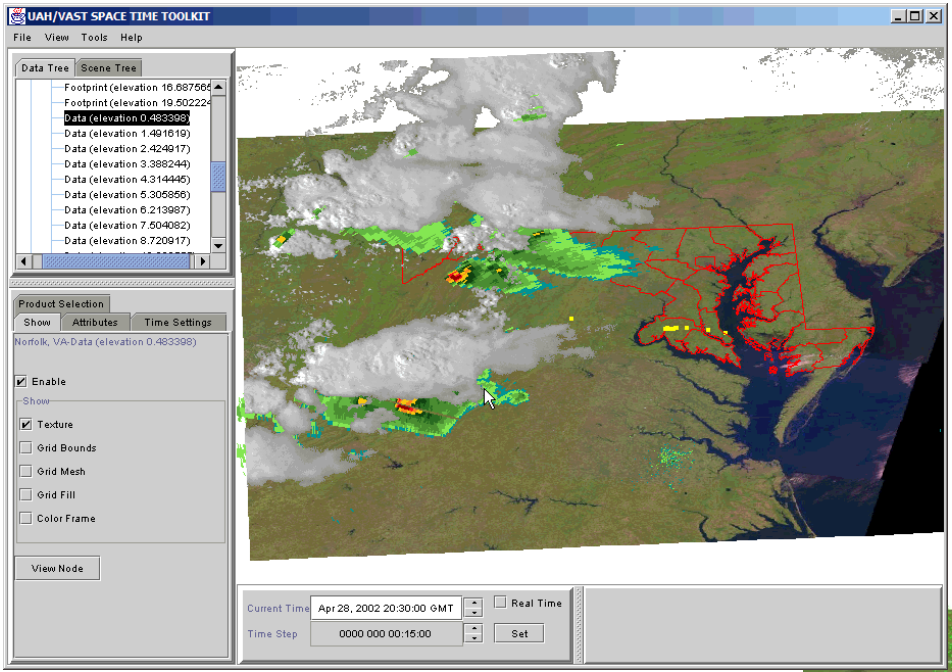
web services and encodings based on Open Standards (OGC, ISO, OASIS, IEEE)

Decision Support Tools

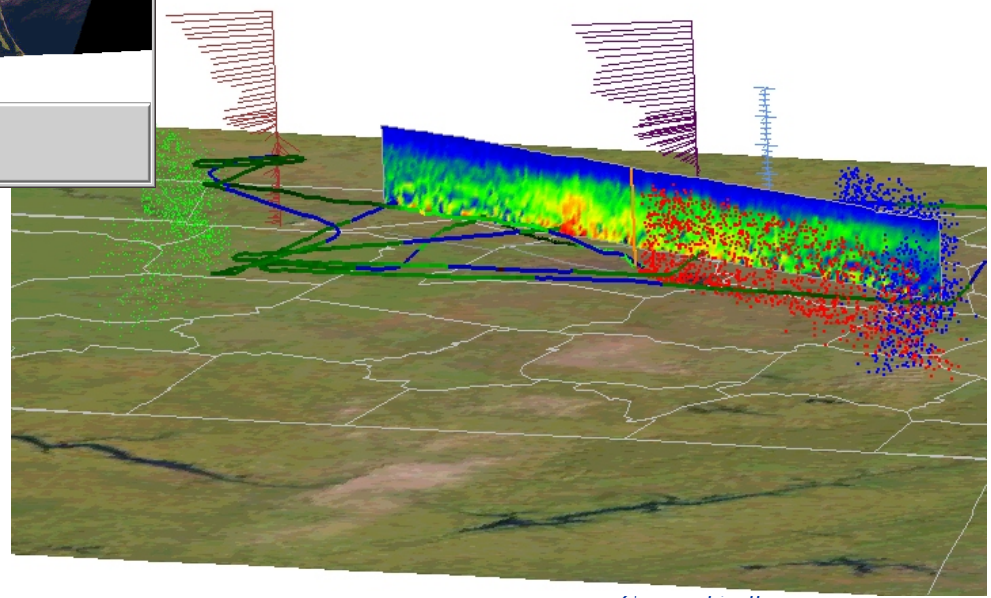


- vendor neutral
- extensive
- flexible
- adaptable

Integration Of Observations From A Variety Of Sensors



We desire the ability to discover and integrate observations from any sensor that meets our needs



OGC

Geographically

Background -1-

1999 - 2000

SensorML initiated at University of Alabama in Huntsville: NASA AIST funding

2001

OGC Web Services Testbed 1.1:

- Sponsors: EPA, NASA, NIMA
- Specs: SOS, O&M, SensorML
- Demo: NYC Terrorist
- Sensors: weather stations, water quality

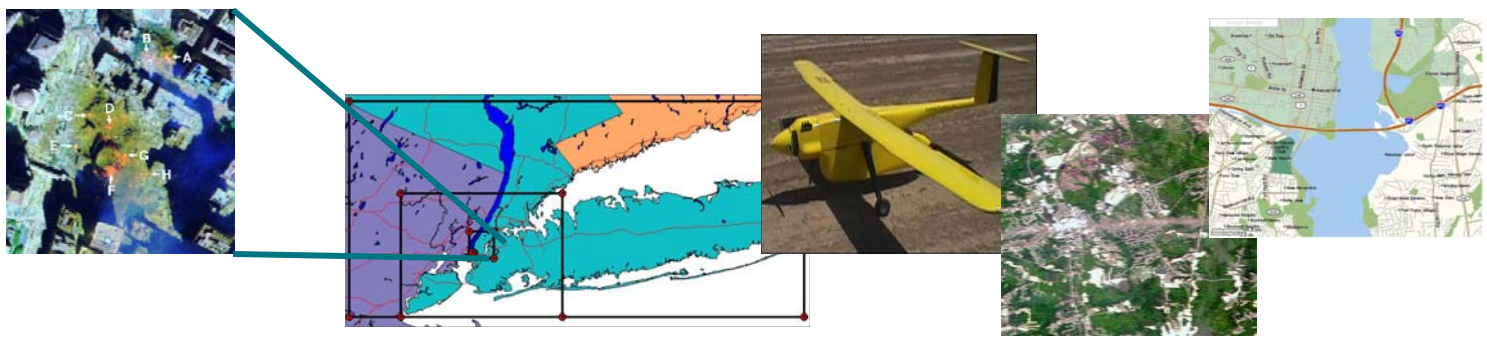
2002

OGC Web Services Testbed 1.2:

- Sponsors: EPA, General Dynamics, NASA, NIMA
- Specs: SOS, O&M, SensorML, SPS, WNS
- Demo: Terrorist, Hazardous Spill and Tornado
- Sensors: weather stations, wind profiler, video, UAV, stream gauges

2003-2004

- Specs advanced through independent R&D efforts in Germany, Australia, Canada and US
- Sensor Web Work Group established
- Specs: SOS, O&M, SensorML, SPS, WNS, SAS
- Sensors: wide variety



Background -2-

OGC Web Services Testbed 3.0:

- Sponsors: NGA, ORNL, LMCO, BAE
- Specs: SOS, O&M, SensorML, SPS, TransducerML
- Demo: Forest Fire in Western US
- Sensors: weather stations, wind profiler, video, UAV, satellite

SAS Interoperabilty Experiment

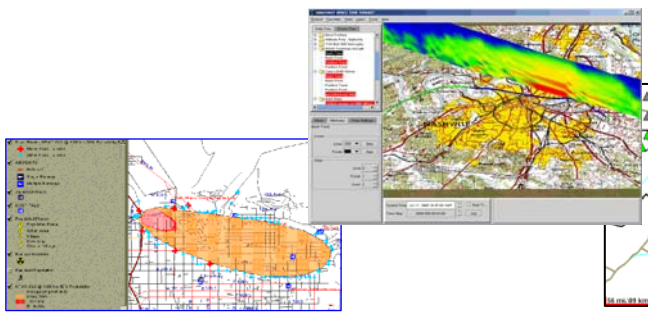
SWE Specifications toward approval:

SensorML – RFC
TransducerML – RFC
SOS – RCF
SPS – RFC
O&M – Best Practices
SAS – Best Practices

OGC Web Services Testbed 4.0:

- Sponsors: NGA, NASA, ORNL, LMCO
- Specs: SOS, O&M, SensorML, SPS, TransducerML, SAS
- Demo: Emergency Hospital
- Sensors: weather stations, wind profiler, video, UAV, satellite

2005 **2006**



SWE Specifications

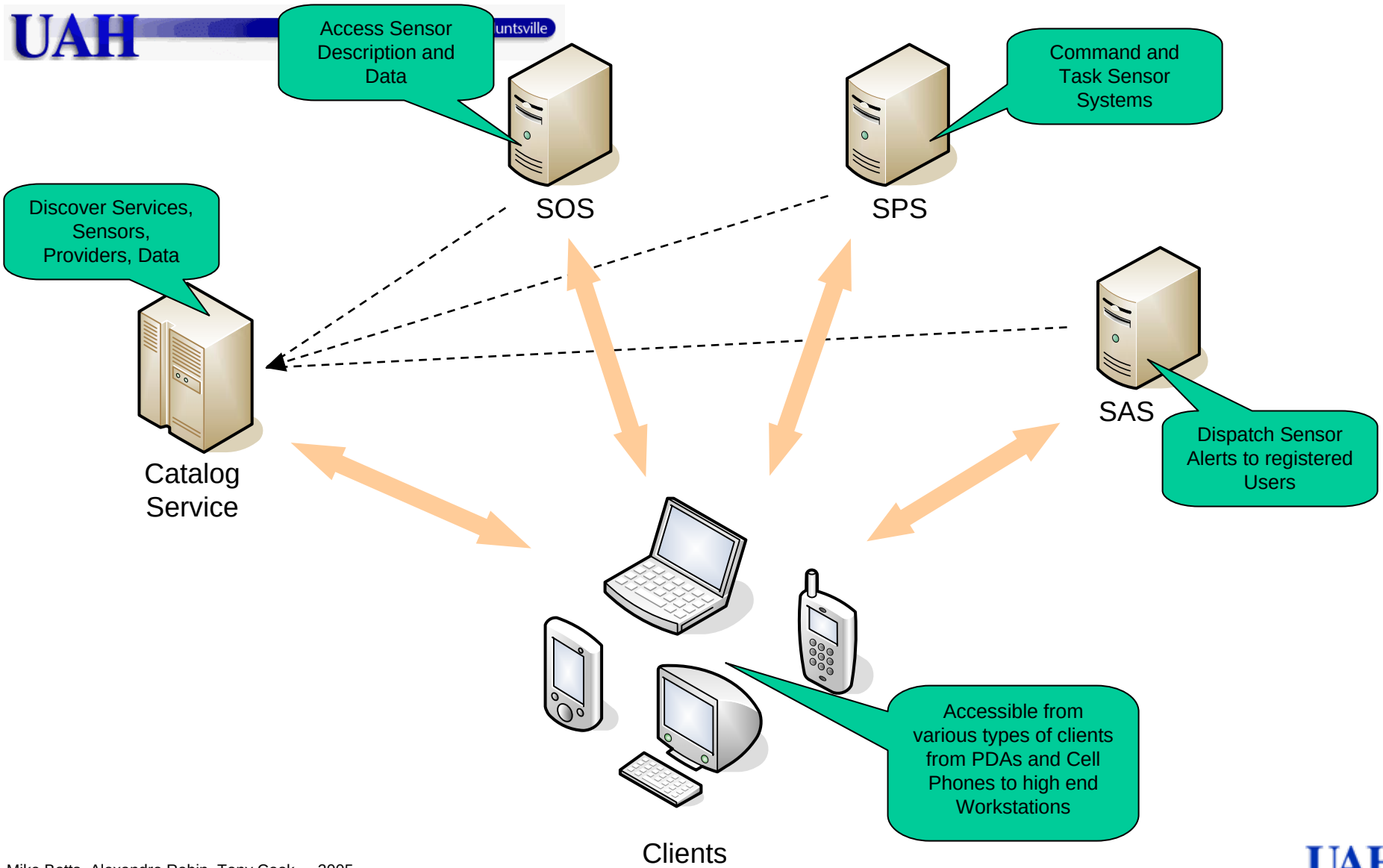
- Information Models and Schema
  - **Sensor Model Language (SensorML) for In-situ and Remote Sensors** - Core models and schema for observation processes: support for sensor components, georegistration, response models, post measurement processing
  - **Observations and Measurements (O&M)** – Core models and schema for observations
  - **TransducerML** – adds system integration and real-time streaming clusters of observations

- Web Services
  - **Sensor Observation Service** - Access Observations for a sensor or sensor constellation, and optionally, the associated sensor and platform data
  - **Sensor Alert Service** – Subscribe to alerts based upon sensor observations
  - **Sensor Planning Service** – Request collection feasibility and task sensor system for desired observations
  - **Web Notification Service** –Manage message dialogue between client and Web service(s) for long duration (asynchronous) processes
  - **Sensor Registries** – Discover sensors and sensor observations

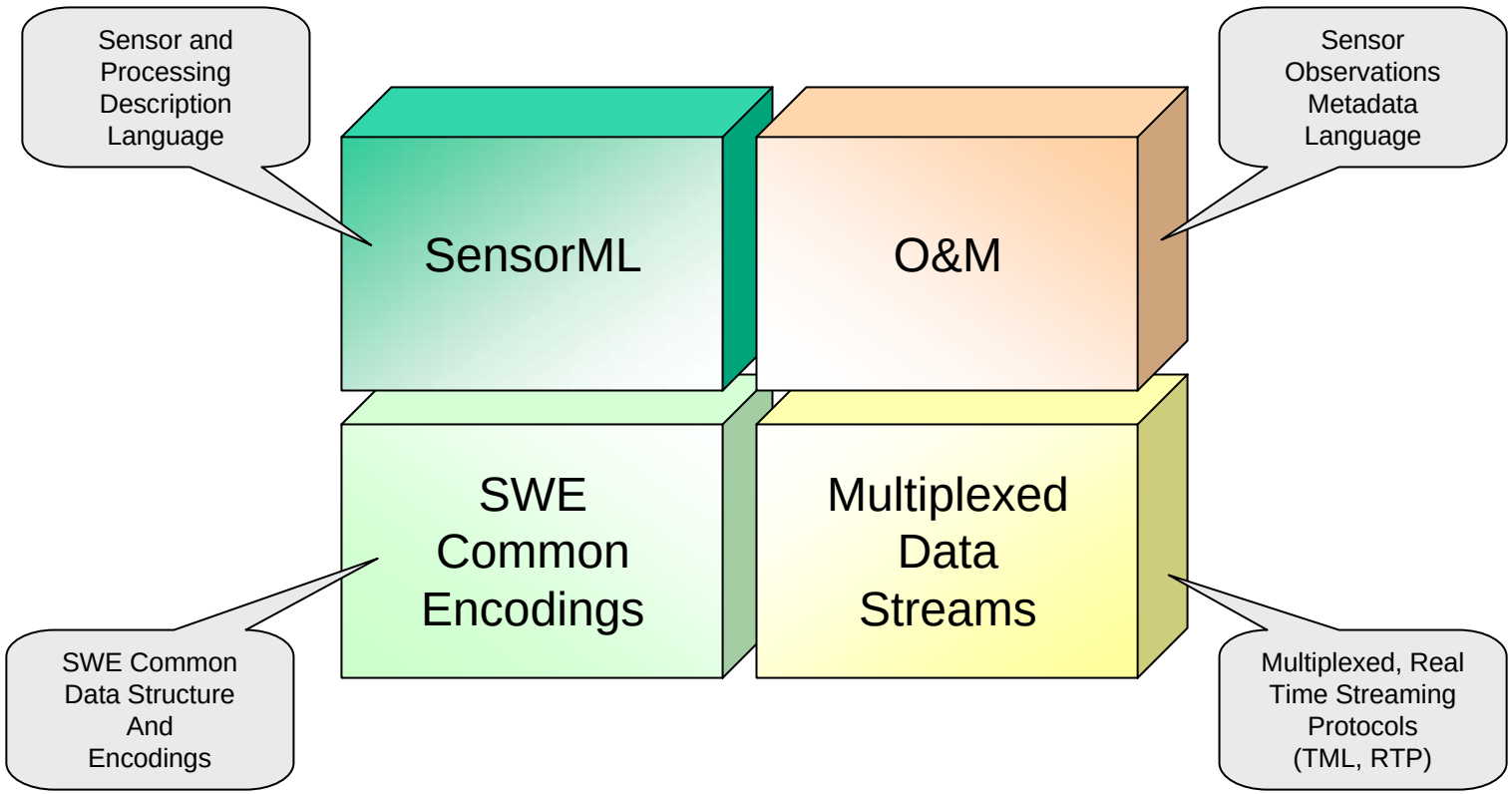
OGC Sensor Web Enablement -4-

- Sensor Web Enablement – Potential Harmonizations
  - **OASIS Common Alert Protocol (CAP)** – being considered as an encoding or portrayal of sensor alerts in SAS
  - **OASIS EDXL** – XML “envelope” for alerts
  - **IEEE P1451** – provides “plug-n-play” capabilities for sensors; working toward automatic conversion between 1451 and SensorML/ TML/ O&M
  - **CBRNE** and **N42.42** – Working on examples supporting these in SensorML

SWE Components – Web Services



SWE Components - Languages



Example SOS Requests and Common Observations

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Weather SOS Requests

GET Request for Weather SOS Capabilities

http://vast.uah.edu:8080/ows/weather?request=GetCapabilities

GET Request for Weather Data measurements

http://vast.uah.edu:8080/ows/weather?request=GetObservation&offering=WEATHER_DATA&time=2004-04-01T05:00:00Z/2004-04-01T06:00:00Z&format=application/com-xml

Airdas SOS Requests

POST Requests Examples - Here

GET Request for Airdas SOS Capabilities http://vast.uah.edu:8080/ows/airdas?request=GetCapabilities

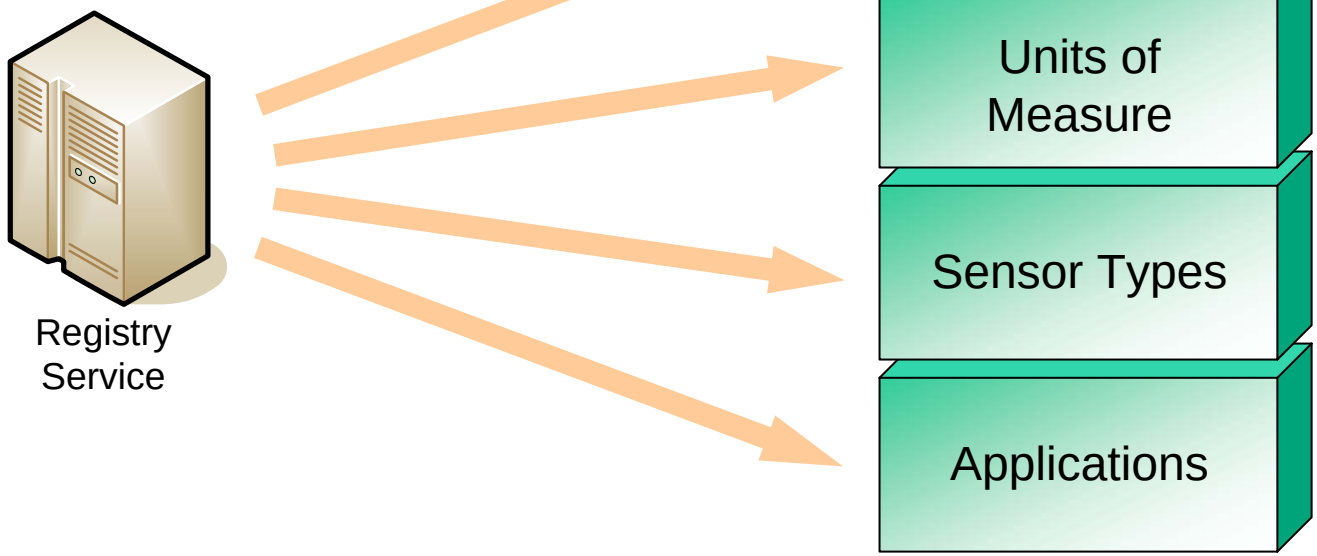
GET Request for Airdas Navigation Data measurements

http://vast.uah.edu:8080/ows/airdas?request=GetObservation&offering=AIRDAS_NAV&time=2003-11-05T19:30:00-08:00/2003-11-05T19:40:00-08:00&format=application/com-xml

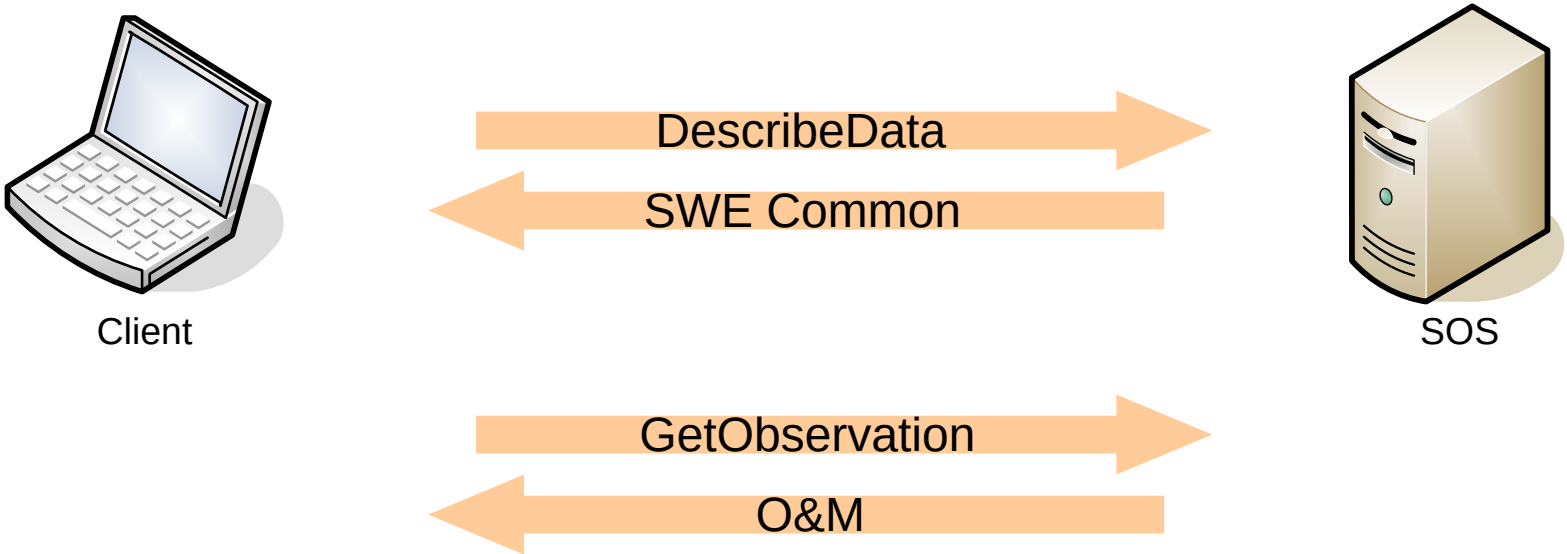
GET Request for Airdas Scanner Data measurements

http://vast.uah.edu:8080/ows/airdas?request=GetObservation&offering=AIRDAS_SCAN&time=2003-11-05T19:19:00-08:00/2003-11-05T19:19:10-08:00&format=application/com-binary-base64

SWE Components - Dictionaries



SWE – Sensor Observation Service



SWE – Sensor Planning Service

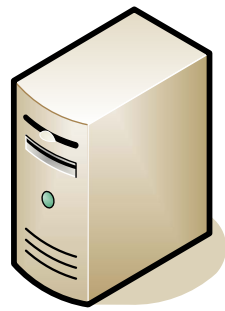
Client

DescribeSensor

SensorML

GetTaskableProperties

SWE Common

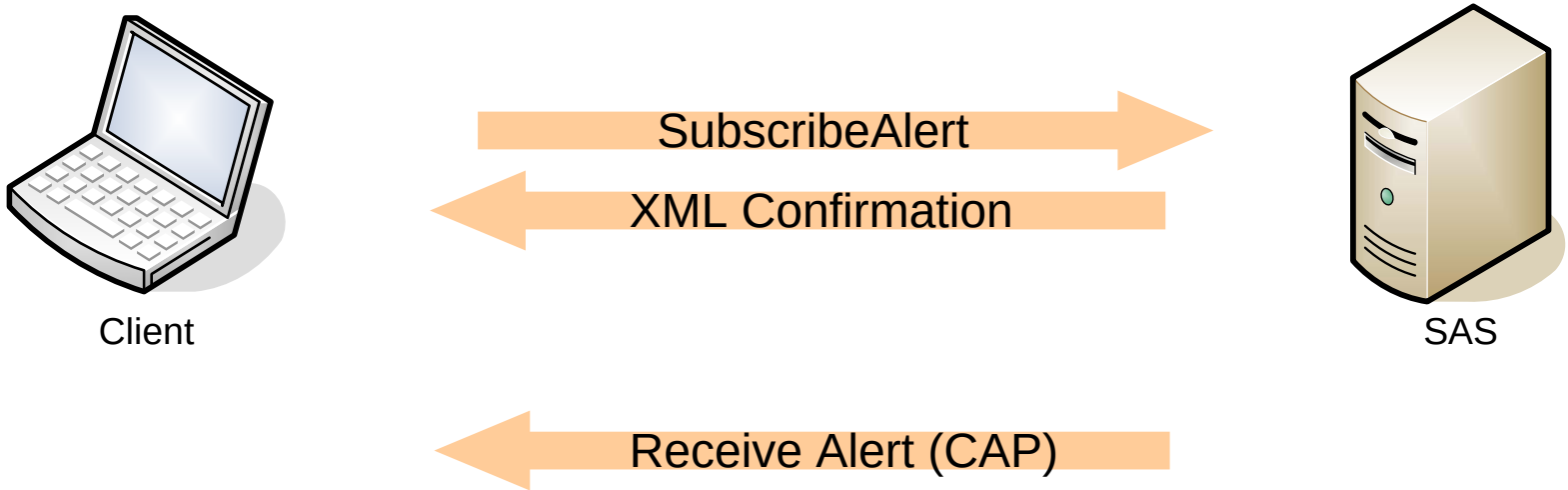


SPS

SendTask

XML Confirmation

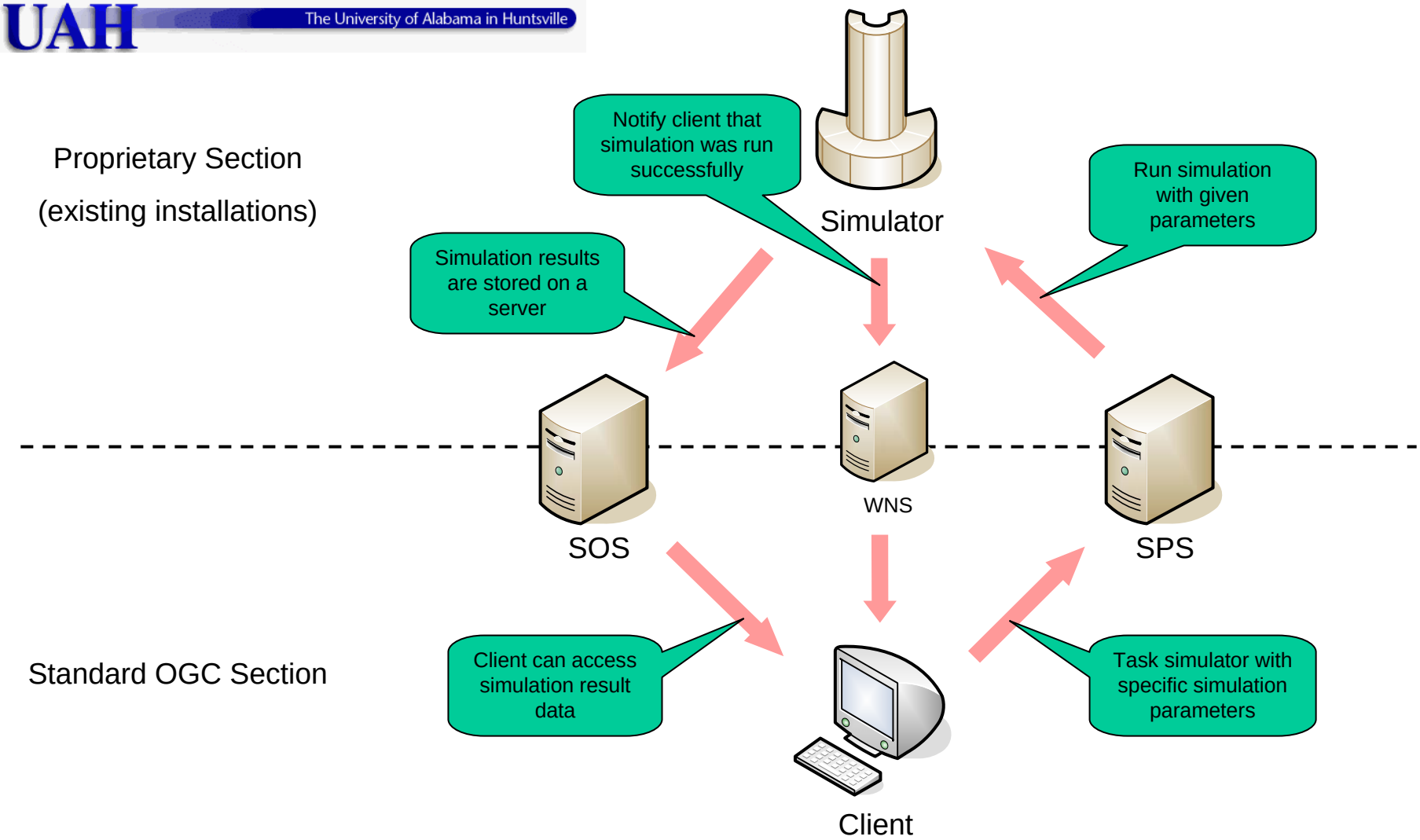
SWE – Sensor Alert Service

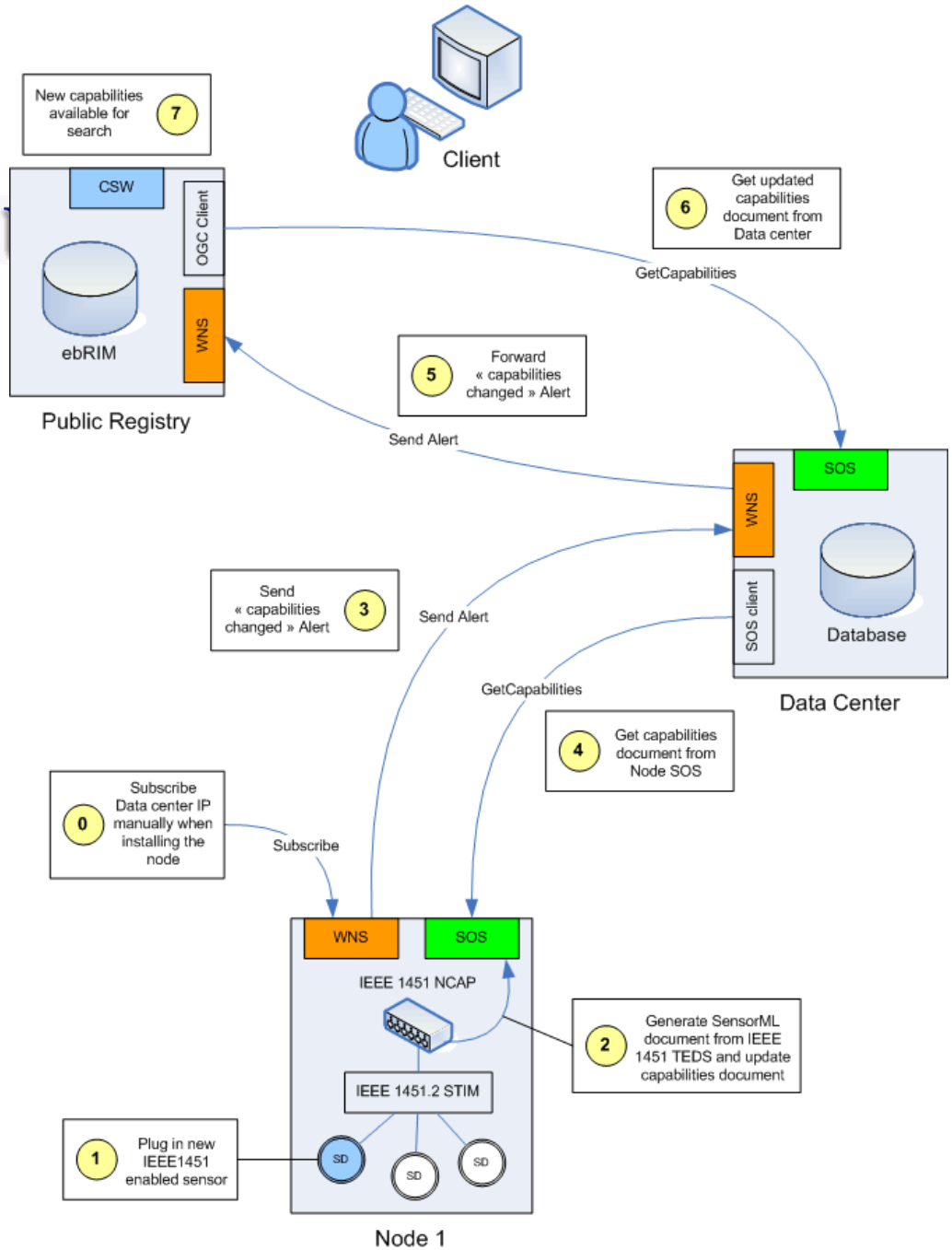


Status

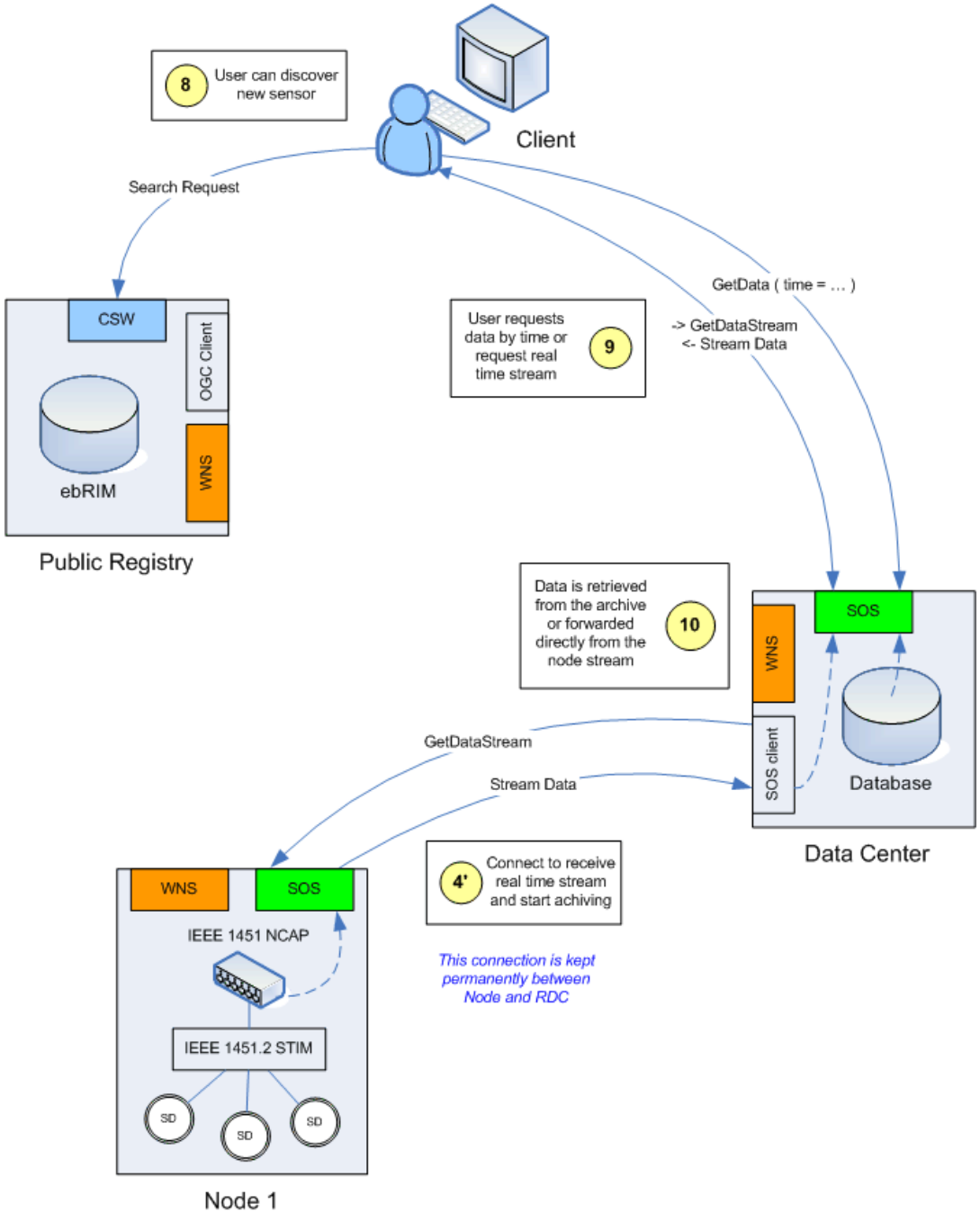
- Current specs are in various stages
  - SensorML – Past RFC; Approved as Version 0.0
  - TransducerML – RFC
  - O&M – Best Practices Paper (soon RFC)
  - WNS – Public Discussion Paper
  - SOS – RFC
  - SPS – RFC
  - SAS – Best Practices Paper (soon RFC)
- OGC Web Services (OWS) 4.0 includes thread for Sensor Web Enablement
  - Execution: June 2006 to December 2006

Integration of Simulation Capabilities

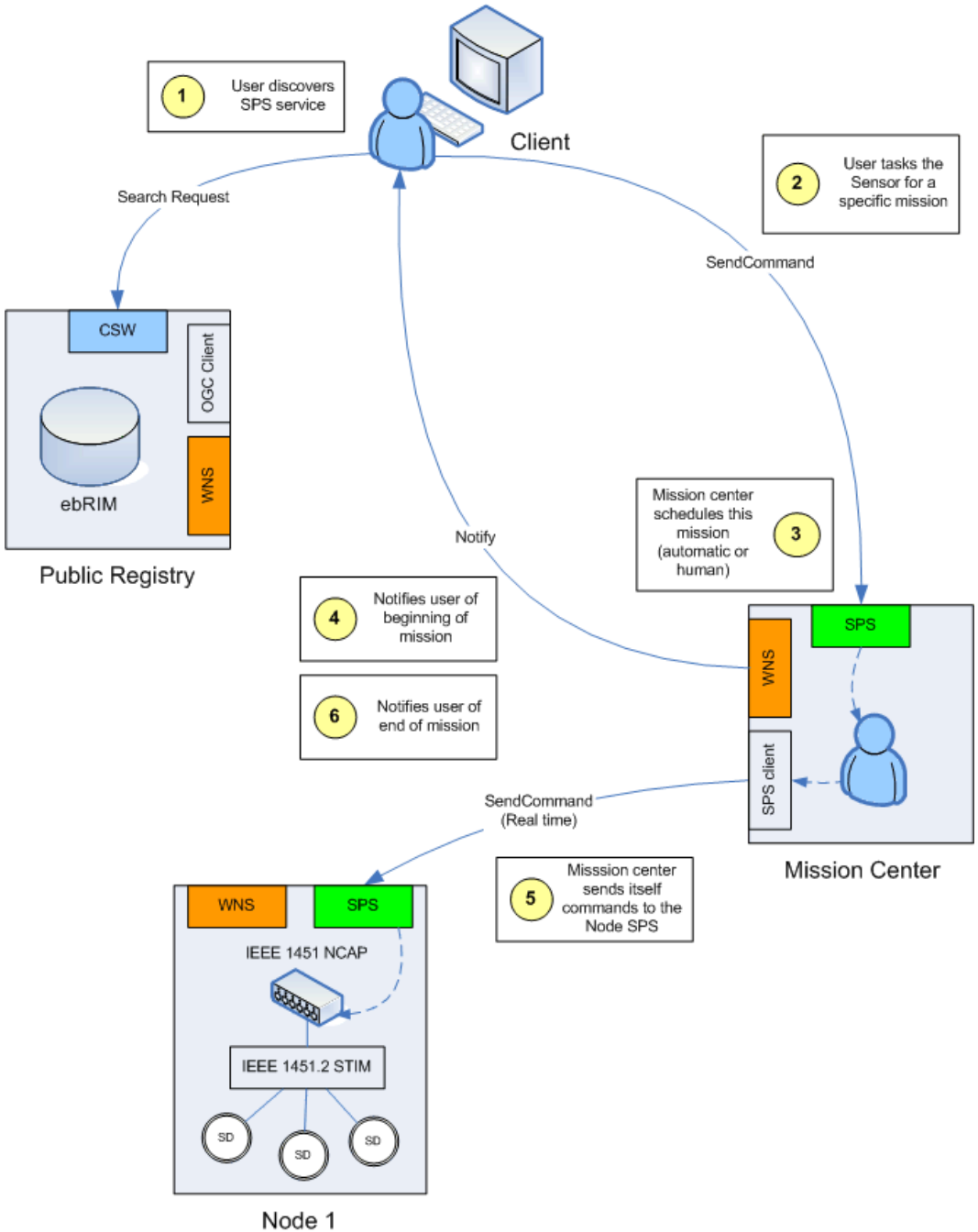




ORNL
Plug-n-Play



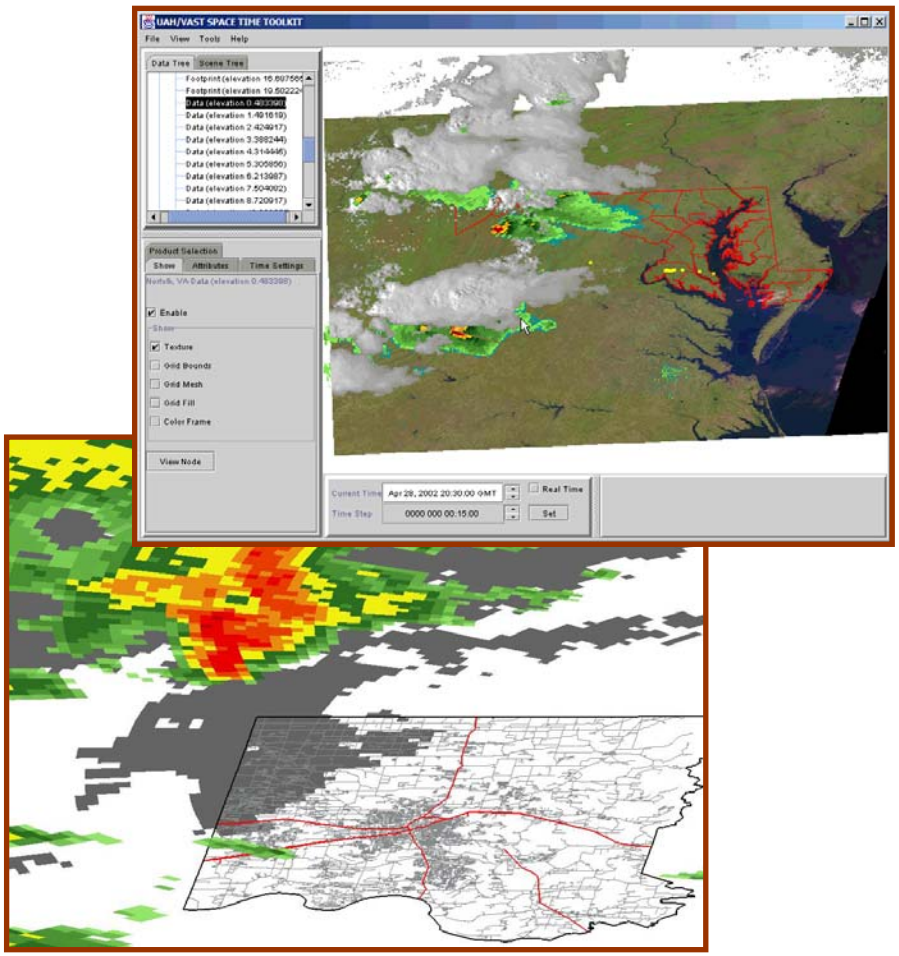
ORNL Client Access

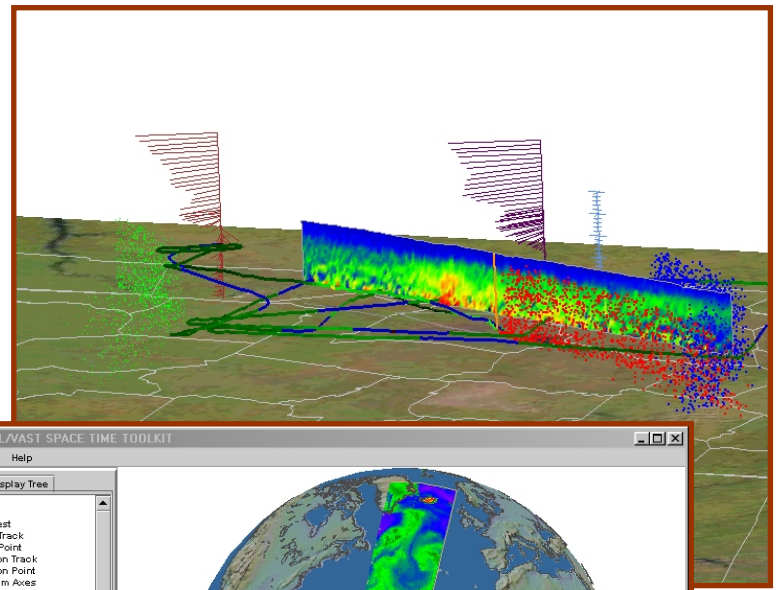


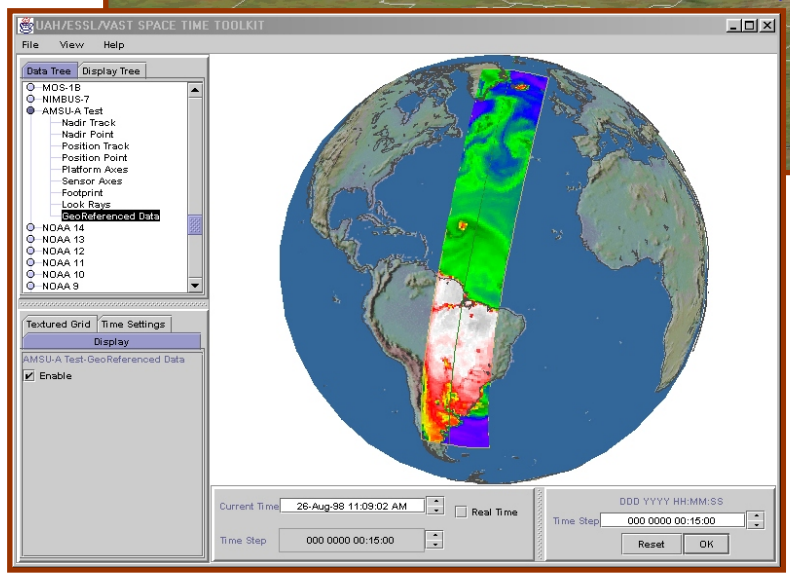
ORNL
Client Tasking

Space Time Toolkit
Sample Applications

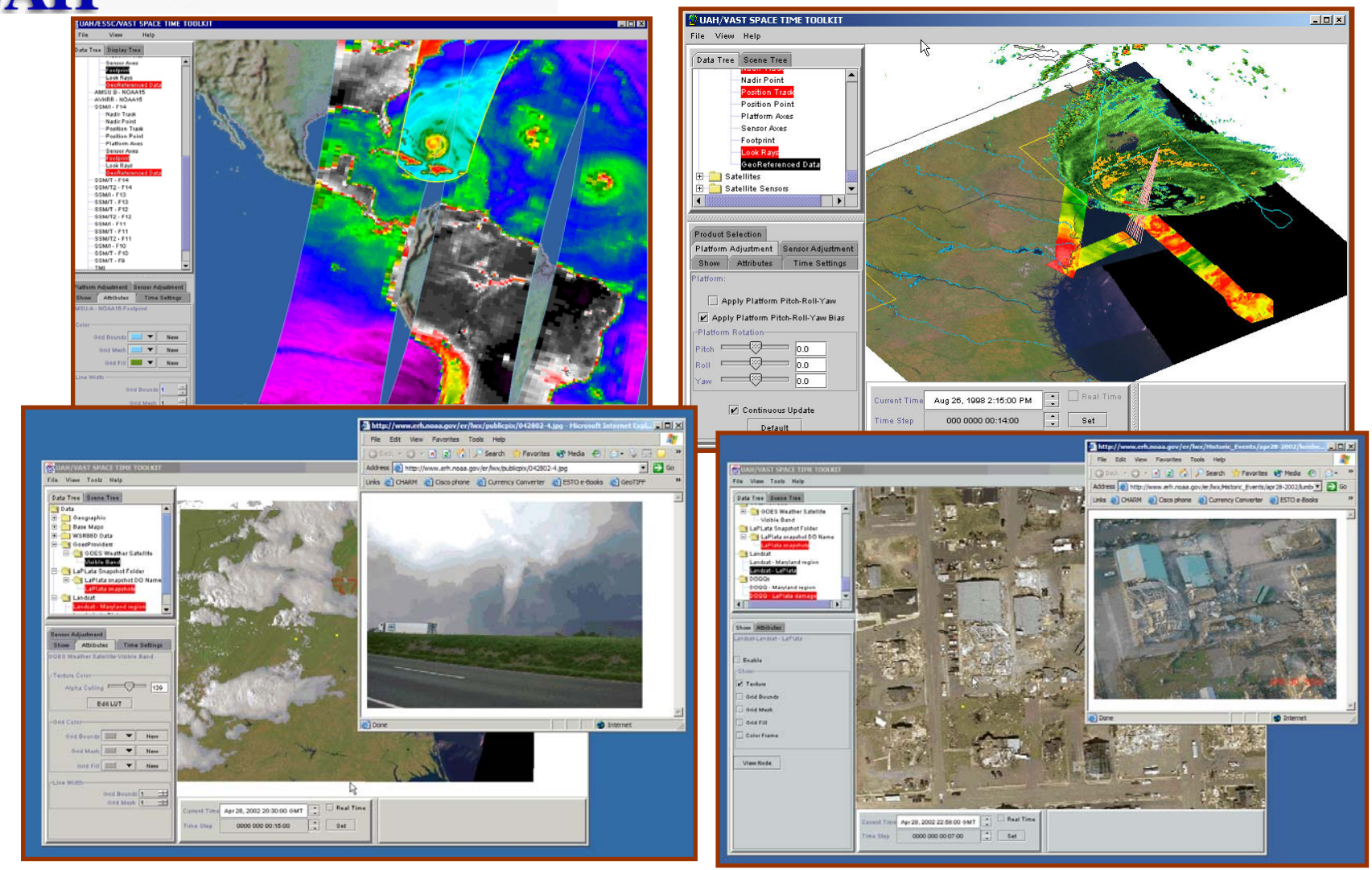
UAH The University of Alabama in Huntsville







Space Time Toolkit
Sample Applications -2-



Relevant Links

- **OpenGeospatial Consortium –**

  http://www.opengeospatial.org

- **Sensor Web Enablement –**

  http://www.opengeospatial.org/projects/groups/sensorweb

- **SensorML –**

  http://vast.uah.edu/SensorML

- **Space Time Toolkit –**

  http://vast.uah.edu/SpaceTimeToolkit